SmartReader Data Loggers

Reference Guide

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SmartReader Data Loggers

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WELCOME

Congratulations on your purchase of a SmartReader Plus data logger. We are confident that you will find it to be a most valuable and useful tool for your data collection applications.

This Reference Guide is designed to be used hand-in-hand with TrendReader 2.0 software and frequently refers to TrendReader 2.0 conventions and procedures. To get the most from your logger, please take time to familiarize yourself with TrendReader 2.0 and its Reference Guide.

For important information on how all SmartReader Plus data loggers work and how to use them, read the Introduction to SmartReader Plus chapter. It will give you an overview of how the loggers work and how to configure them for your application. Next, read the chapter that deals specifically with the type of SmartReader Plus logger you have.

SECTION 1 SmartReader Data Logger

1.1 Introduction to SmartReader Data Loggers

SmartReader data loggers are easy-to-use, battery-powered data loggers. Pocket-sized and rugged, they can be used in a wide range of environmental and industrial applications. Different SmartReader models are available to directly measure and record variables such as temperature, relative humidity, pressure, electric current, analog voltage, current loop and pulse. Each model can reliably record time-based data for later analysis, by TrendReader software.

TrendReader software must be installed and ready to run prior to making use of the setup instructions in this section of the guide.

1.1.1 Features

SmartReader data loggers share many common features that make them useful tools for data collection:

- Pocket-sized
- Solid-state components - no moving parts
- Low-power microprocessor controlled circuitry
- Precision on-board thermistor temperature sensor
- High capacity lithium battery.
- Quartz clock crystal
- Magnetic backing and secure locking hole
- Rugged die-cast Noryl® case
- Convenient terminal block connector

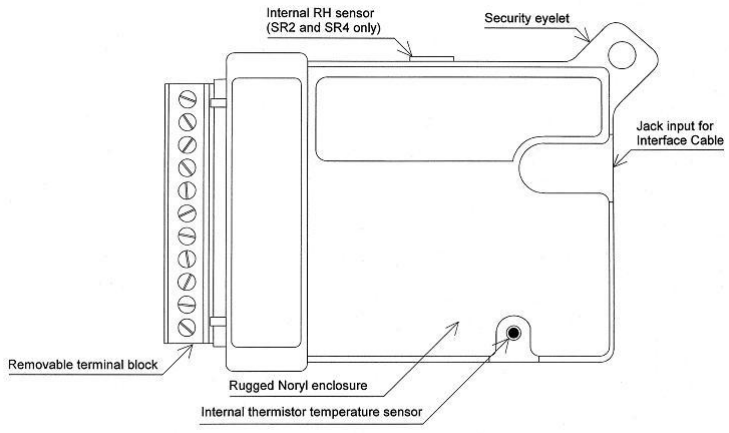

Figure 1

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1.1.2 Description

SmartReader loggers can run continuously, constantly measuring and recording readings from any enabled channel. They can also start logging at a specified time. Self-powered by a long-life lithium battery that will provide years of reliable operation, your SmartReader can work independently from any external power supply or computer. When you are ready to look at the data it has collected, it can transfer all information to your computer through the use of TrendReader software.

Main Components
The main components of the SmartReader data loggers include:

- a memory chip that has the capacity to store up to 32,768 readings
- a microprocessor with an 8-bit analog-to-digital converter (A/D) that converts all input signals to digital values
- a quartz clock crystal that accurately keeps track of time and regulates the taking of readings
- an accurate on-board thermistor that the logger uses to measure ambient temperature via changes in resistance
- a lithium battery that provides power to the logger and internal or external sensors.

1.1.3 Programmed Operation

SmartReader data loggers run according to settings that you program. These pre-selected settings are stored in the logger's memory chip and instruct it to:

- take readings at regularly-spaced intervals
- take readings from specific channels that you enable
- associate each channel with an equation in TrendReader software
- start readings with or without a delay
- take readings continuously, or stop when memory is full

1.1.4 How SmartReaders Loggers Take Readings

Each SmartReader data logger has an on-board thermistor that you can use to record ambient temperature. Depending on which SmartReader model you have, you can turn this temperature-monitoring capability on or off using software. You can also record other information by connecting sensors, transducers or external circuitry to the plug-in terminal block.

SmartReaders can record up to 32,768 readings in two selectable modes:

1. First-in, First-out (FIFO). In this mode the logger continues to take readings when its memory is full (to make room, it discards the oldest reading every time it adds a new one). Thus, the memory will contain a "sliding window" of information.

2. Stop when Full. The logger stops recording when its memory is full.

You can set the time interval at which your logger saves readings using TrendReader

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software. The sampling rate you select will apply to all enabled channels. At a sample rate of eight seconds, one reading is taken every eight seconds and saved to memory. As you slow the sample rate the logger begins to average readings before saving them to memory. To do this the logger takes a reading every eight seconds, but instead of transferring this directly to the logger's memory, it stores the readings in a buffer (a temporary memory) where it is retained until the sampling interval is over.

When you backup a logger's data into your computer, the correct time and date are referenced to each reading. All readings are then individually time and date stamped and processed by an equation associated with each logger channel. The result is a collection of accurate time-based data ready for detailed graphing and analysis.

1.1.5 How to Use SmartReaders

Using your SmartReader data logger for most applications is a simple process. With proper planning, setup and installation of your data logger, you can be assured that the information you collect will be both correct and useful. The following provides general procedures for using SmartReader data loggers. For additional and specific information on these steps, refer to the chapter in this manual that deals with your particular SmartReader model.

Planning
Proper planning is the key to successful data logging. Time spent in this stage will help you save time and frustration later. To help you plan, answer these questions:

- *What exactly do I want to measure?*
- *Where is the best place to measure?*
- *How long do I want to monitor for?*
- *Should other variables be monitored simultaneously?*

Setup
To set up your SmartReader data logger you must first have TrendReader software installed and running on your computer. You can then configure your logger with various options by talking to it via the interface cable.

Set Sample Rate
Always confirm the sampling rate (how often the logger takes readings) to make sure it will be acceptable for your application. You can alter the frequency at which your SmartReader data logger records readings by changing the sample rate. You can choose rates from 8 seconds to 5 days. The sample rate chosen will apply to all the active channels on the logger.

To help determine which sampling rate you should choose, answer these questions:

- *How long do I need to record data?*
- *How much time will elapse between when I retrieve the logger and download the data to my computer (for example, the trip back to the office)?*
- *How often do readings need to be taken?*

Making External Connections
If you are using your SmartReader data logger to monitor external modules, sensors, or

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circuitry, make sure the connections are tight. Also, make sure the terminal block is snapped securely into the logger.

For permanent applications, wiring connections can first be made to the logger's removable terminal block. The terminal block can then be attached (with glue for example) to a permanent fixture. When it comes time to analyze data, the logger can simply be unplugged from the terminal block and brought back to your computer. After backing up the data, the logger can be returned and plugged back into the terminal block. Extra terminal blocks are available from your sales representative. When unplugging the terminal block from your logger, use care to pull it straight out so as not to break the plastic casing.

Enable Channels
Always make sure that you have enabled and verified the correct channels for your application. This is very important as it can be very distressing to find out later that the information you hoped to collect was from an inactive channel. You can selectively enable additional channels in your SmartReader as required. However, in order to avoid using logger memory unnecessarily, disable any channels which are not required.

Clear Memory
Before starting a logging session, clear the logger's memory. This will help to keep the collected files smaller as well as decrease the time needed to backup the logger later. Note that clearing the memory is automatic if you save setup changes (i.e. assign different equations, change sample rate, etc.)

Test
You can directly read the values that your SmartReader data logger is sensing using the Realtime capability of TrendReader software. This test gives you the opportunity to check your logger setup and make any necessary changes before starting the logging session.

Label
If you are working with more than one data logger, label each logger, identifying the task and location before you distribute them throughout a building or system. To do this, you can simply use a shipping tag. Later, when you retrieve them to graph their data, you will know what each graph refers to.

Mounting
Use the magnetic backing to conveniently mount your logger on metal surfaces like ductwork or electrical control cabinets. If you are concerned about theft, lock your logger to a permanent fixture using the locking tab or take advantage of its small size and hide it completely out of view. Because SmartReader loggers are so light, you can use special mounting fasteners like Velcro® fasteners to attach them to almost any surface. Make sure your logger's mounting method will last the full length of your logging session.

Do not rely on the logger's magnetic strip for adhesion if the mounting surface is uneven, unstable or above 65°C (150°F).

Cold or Humid Environments
Make sure that the environment you will be placing your logger into will be acceptable by referring to the Specifications in this chapter. If conditions are not acceptable for the logger,

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consider using a protective enclosure. For humid environments, you can protect your logger simply by placing it in a zip-lock plastic bag.

When you place your SmartReader logger in a cold environment, make sure condensation will not settle on the logger when you bring it back into warmer surroundings, such as an office. The best way of preventing condensation is to place the logger in a container and include a desiccant (a material that absorbs moisture). When you bring your logger back to your computer, leave the logger in the container until it has had a chance to warm up to the surrounding temperature. You can then take it out and analyze it.

Keep Track
Be sure to keep a record of where you have placed each logger in a building or system plan. You will save time looking for them when your data gathering session is over. Also, keep track of when you placed the loggers in the area you are monitoring. This will help when producing graphs on your computer. It may be helpful to label (shipping tag) each logger so you can properly identify and differentiate it from other loggers.

Analysis
After sufficient time has passed for the logger to obtain a representative profile of data, it is time to analyze the information. If you are retrieving the logger from the field, bring it back immediately to your computer for analysis.

In order to analyze your SmartReader logger's data, you must first transfer a backup copy of its data to your computer. To do this, see Backup in the TrendReader Guide. After transferring your information to the computer, the data is automatically copied to disk and time and date-stamped.

You can find a detailed description of all software functions in the TrendReader guide.

1.1.6 Specifications

General

Size:	107 x 74 x 22mm (4.2" x 2.9" x 0.9")
Weight:	110g (3.75 oz.)
Case Material:	Noryl® Plastic
Operating Limits:	-40 to 70°C (-40 to 158°F) and 0 to 95% Relative Humidity (non-condensing)
Clock Accuracy:	±2 seconds/day
Battery:	3.6 Volt Lithium, 1 Amp-hour
Power Consumption:	5 to 10 microamps (continuous)
Battery Life:	Ten years (under normal use) factory replaceable
Memory Size:	32,768 readings

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Sampling Methods:	**1**. Continuous (First-in, First-out) **2**. Stop when full (Fill-then-stop)
Sample Rates:	User selectable rates between 8 seconds to once every 5 days.
Resolution:	8 bits (1 part in 256)
Resistance to X-rays:	Tested for protection against a 160kV dose @ 5 mA for 30 seconds (150 mA-sec) @ 38 in. F.F.D. (about 100 times that of an airport X-ray machine). Tested for protection against Gamma Ray (equivalent to 0.137 - 1.38 mega volts) IR 192 - 28 curies @ 30 second exposure source to object distance 5".

Internal Temperature Sensor

Type:	NTC thermistor; 10k ohms at 25°C (77°F)
Range:	-40 to 70°C (-40 to 158°F)
Accuracy:	±0.2°C between 0 and 70°C (±0.3°F between 32 and 158°F)
Resolution:	0.4°C at 25°C (77°F) Better than 1.0°C (1.8°F) between -25 and 70°C (-13 and 158°F) Better than 2.0°C (3.6°F) between -40 and -25°C (-40 and -13°F)
Equation:	Use Equation 45 in TrendReader software

Specifications are subject to change without notice.

1.1.7 Approvals

Meets Part 15 for Digital Devices of the Code of Federal Regulations of the Federal Communications Commission (FCC). Meets Class A radiated and conducted emission requirements of Section 2 of the Radio Interference Regulations of Communications Canada, IEC801-2, 3, 4 and EN55011 covering ESD, RFI Immunity, EFT/Burst and Radiated Emissions respectively for the Commission of the European Communities (CE).

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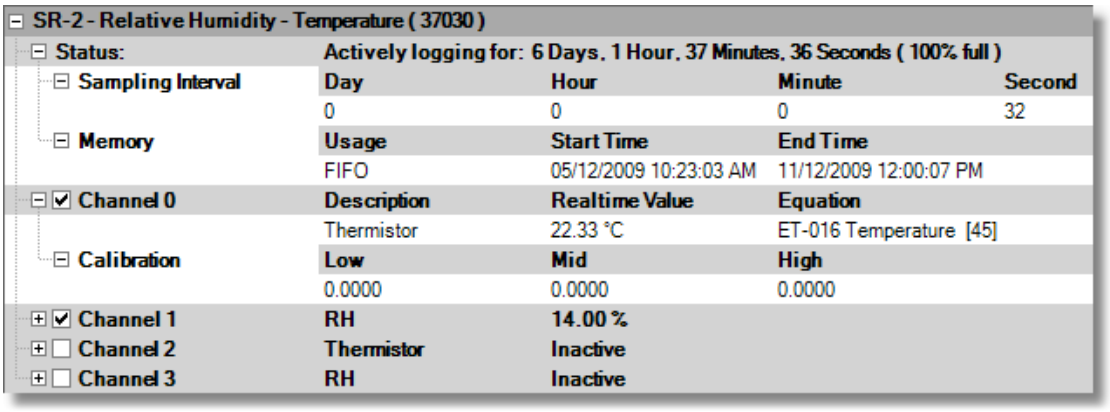
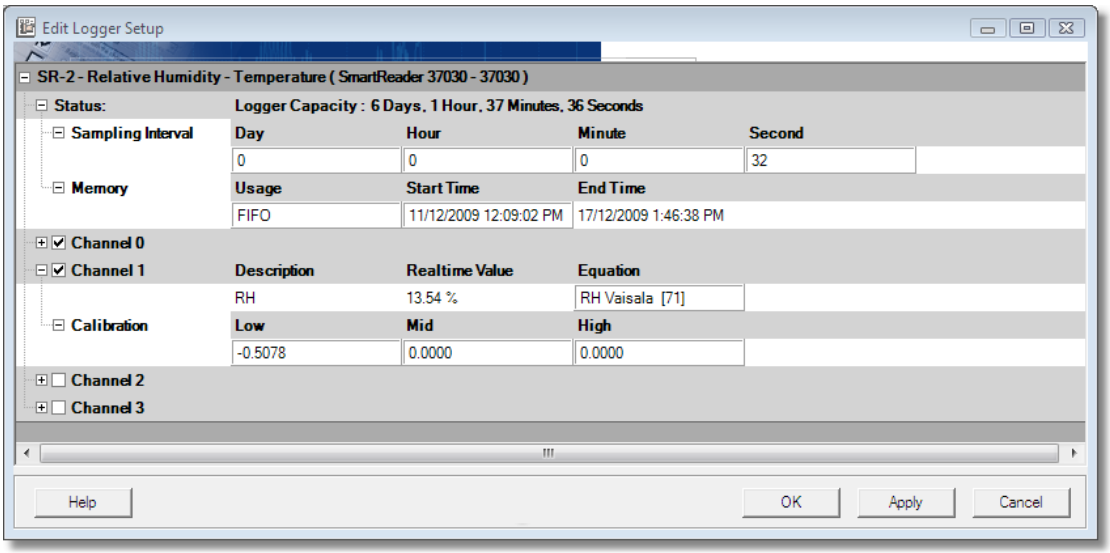
1.2 SmartReader Software Driver

TrendReader software uses a software driver to communicate with SmartReader data loggers. However, TrendReader software will not work with loggers with a serial number less than 20,000. The software driver takes the form of two windows. The Status window, shown when you contact the logger, is used to display the settings currently stored in the data logger. The Setup window, shown when you select Edit Setup, is used to alter the current settings and apply the changes to the data logger. The settings are divided into two main sections: Status and Channels. Status contains information about sampling and memory. Each channel of the logger contains information about the description, equation and Realtime value, and calibration associated with the channel. You can control the level of detail that you see for the settings by clicking on the "+" and "-" buttons at the left side to expand and collapse the nodes.



When you want to clear the logger's memory and start a new logging session with new parameters, select **Edit Setup** from TrendReader. In the Edit Logger Setup window, make any necessary changes. To implement your changes, you can either click on **Apply** or **OK**. OK will implement the changes and close the window whereas Apply will leave the window open, thereby allowing you to make changes in other features.



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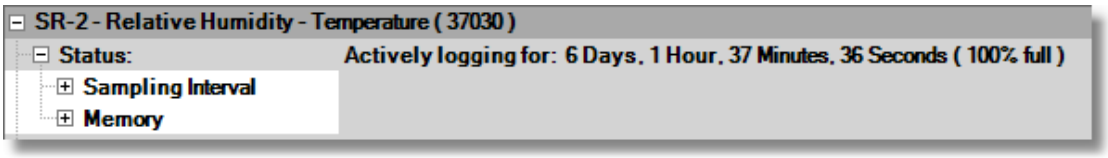
1.2.1 Logger Status

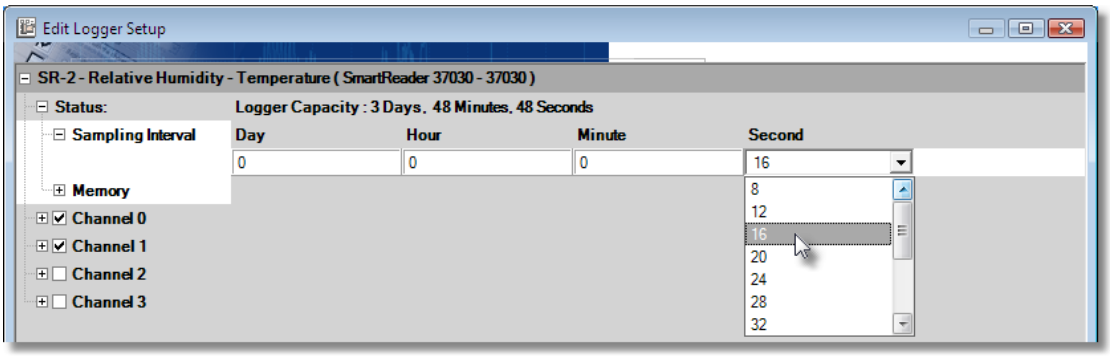
When you contact the logger, the logger status is displayed. The Status line indicates whether the data logger is actively logging, waiting to start or dormant. If you set up the logger with no delay, it will immediately start logging and the status will show the number of readings, or samples, that have been taken. If you want to have the logger wait before it starts logging, set the start time accordingly. The Status subsections are Sampling and Memory.


SR-2 - Relative Humidity - Temperature (37030)
Status:
Actively logging for: 6 Days, 1 Hour, 37 Minutes, 36 Seconds (100% full)
Sampling Interval
Memory

1.2.1.1 Logger Sampling

The Sampling subsection indicates the sample rate, which is the frequency with which a logger takes readings. The rates available are from once every 8 seconds to once every 5 days.

To set the sample rate, click on the desired time unit and select the value from the drop-down list as shown.



To find out more about sample rates and to view a set of sample rate tables, see Appendix D Sample Rates.

1.2.1.2 Logger Memory

The Memory subsection indicates how the data is stored in memory and what the start and end times (or capacity) are for the data logging. In the FIFO (First In, First Out) mode, the logger continually stores data and when the memory limit is reached, the new readings start to overwrite the oldest readings. In this method, the logger is always collecting data, but only saves the most recent data in its memory. In the Stop When Full mode, when the memory limit is reached, the logger stops recording.

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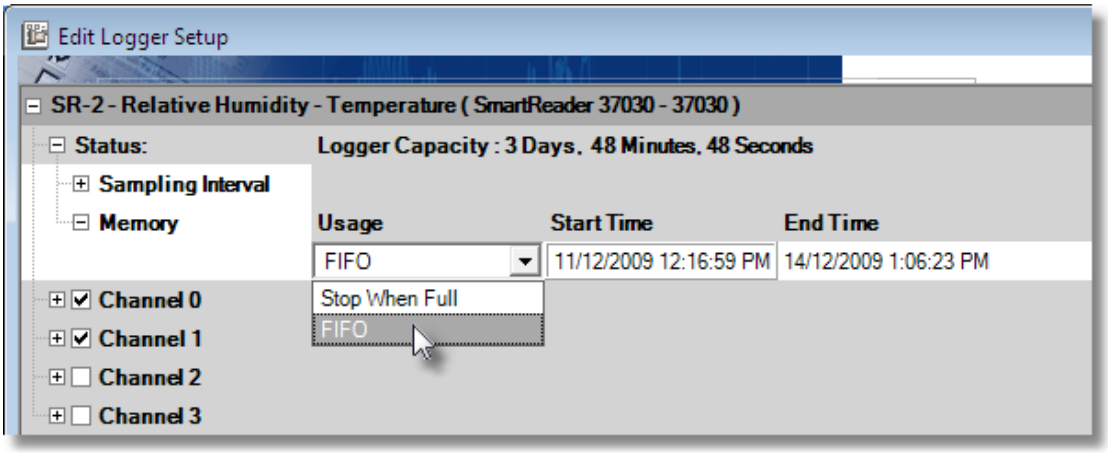
The length of time for data capture of the logger is determined by the number of active channels and the sampling rate. To find out more about how the capacity is affected by the sample rate and active channels, see Appendix D Sample Rates.

To set how the logger stores its data, click on the Usage field and select FIFO or Stop When Full.



To set when the logger will start recording click on the Start Time field. Next, click on the small button that appears at the right. This will pop up a form allowing you to set the date and time. Highlight the date or time and enter the appropriate value. You can also click on the drop-down list arrow to bring up a calendar. You can set the logger's starting time for just over

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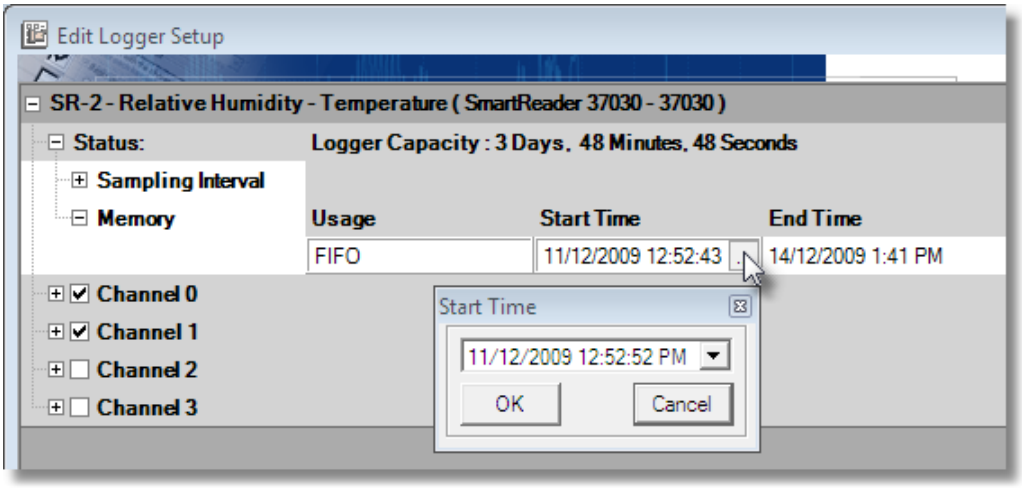
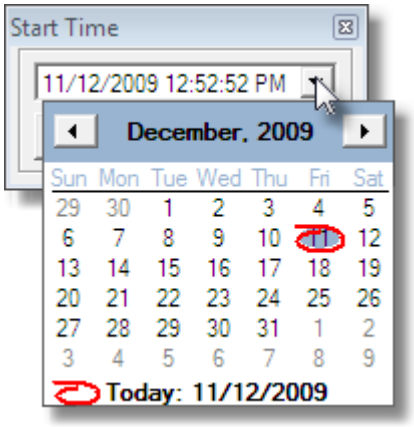
2 years ahead.





1.2.2 Logger Channels

The Channels section indicates what channels are enabled (there is a check mark beside the channel number) and provides information specific to each channel. When you enable a channel on a logger, it becomes an active channel and it continually records readings and stores them in the logger's memory. You should disable any channels you are not using so that there is as much memory as possible available for the active channel(s). The Channel subsections are Information and Calibration.

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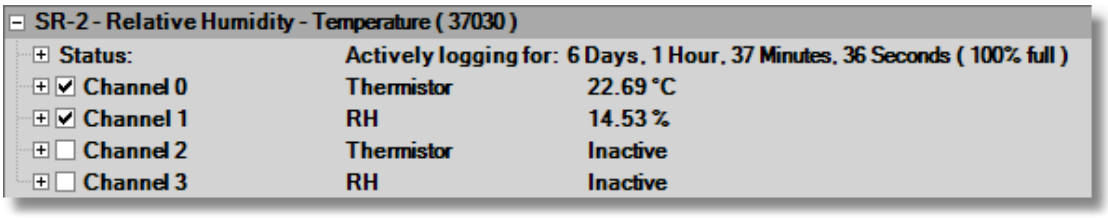
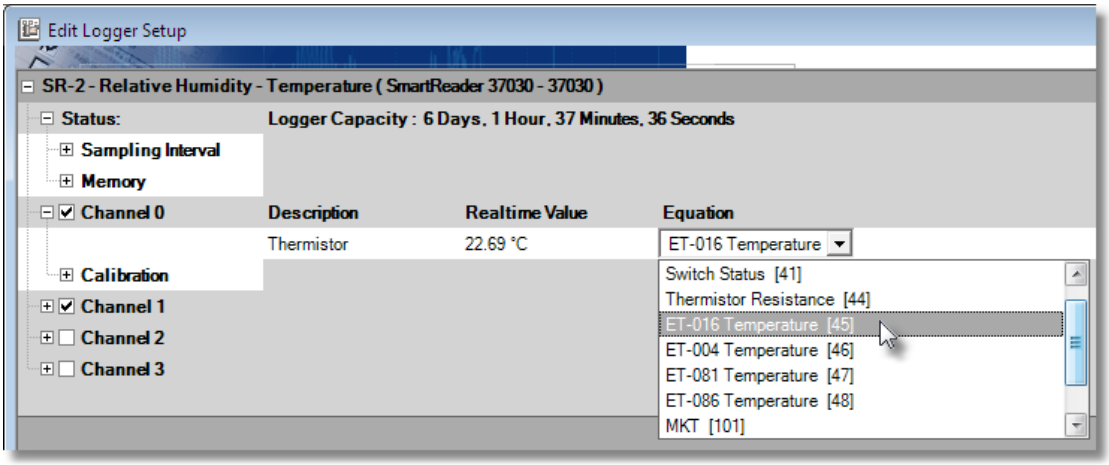
1.2.2.1 Channel Information

When you contact the logger, the logger status is displayed. The Channel line gives the description and the Realtime value, if Realtime is turned on. The Realtime value is based on the equation that you select for the channel. The equation is selected in the Setup window but is not shown in the Status window.



The logger collects and stores raw data readings. An equation is used to transform the raw data into measurement units, such as °C, with the current reading shown as a Realtime value. You can use built-in equations or you can create your own custom equations. See Equations in the TrendReader guide for further information. To set the equation, click on the Equation field and select the equation from the drop-down list. To help you select the proper equation, the Realtime value using the currently selected equation is shown. *



Some channels compensate their output by using the value of another channel. For example, the calculated value for an RH channel depends on the reading of the RH sensor and the value of the temperature channel. In such cases, the compensation channel must output in the correct units. In the case of RH, for example, the temperature channel must output in units of temperature. Using units of byte counts, switch status, or resistance will give invalid results.

* Note that if a custom equation is not available when Edit Setup... is selected (e.g.: deleted) then the equation will be shown as unknown. If a new equation is not selected the Realtime value will not display correctly. If the logger is backed up the channel will be disabled then changes to the equation can be made in the graph using the Lines Tab in Graph Settings.

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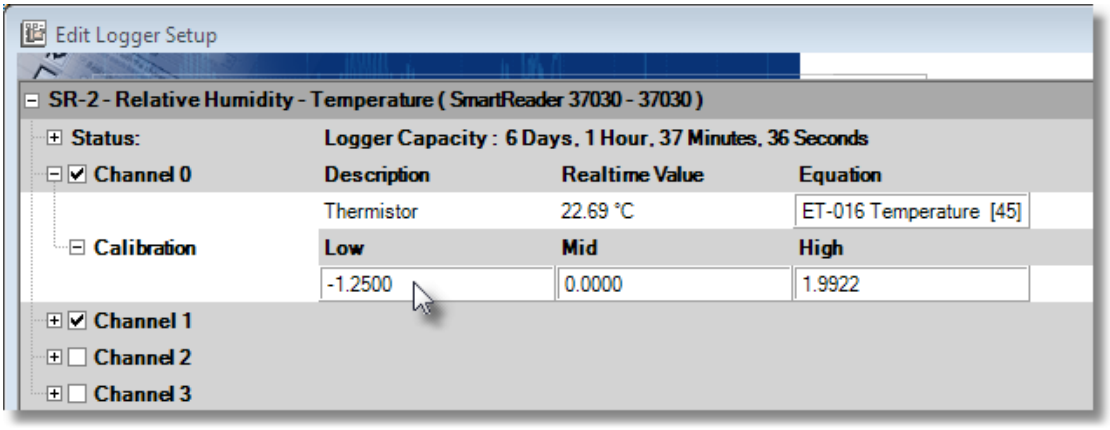
1.2.2.2 Channel Calibration

The Calibration subsection shows the Low, Mid, and High calibration values. These values are used to adjust the readings of the logger in order to make the output more accurate. To set each calibration value, click on the appropriate calibration field and enter the value.



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1.3 SmartReader 1 Temperature Logger

The SmartReader 1 is an easy-to-use logger for recording temperature in a wide range of applications such as HVAC testing/balancing, property management studies, and transportation of perishable goods.

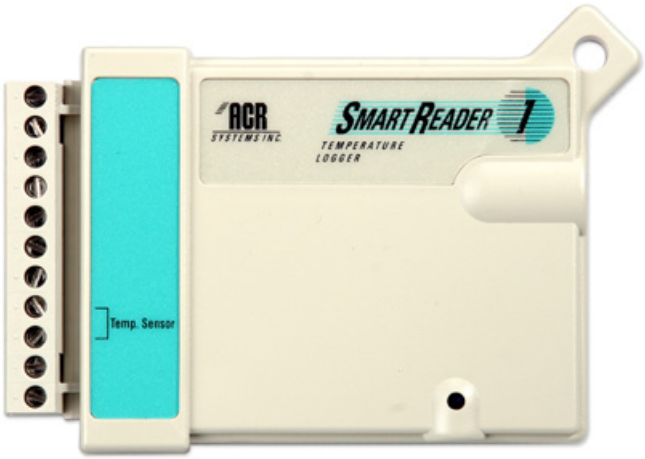

Figure 1.1: SmartReader 1

1.3.1 Description

The SmartReader 1 has an on-board thermistor temperature sensor and an external temperature sensor channel for remote measurements with an optional probe.

1.3.2 Setup

Make sure you have enabled the channels you want to use. If you are not using a channel, disable it to save logger memory.

Channel	Description	Equation
0	Internal Temperature	45
1	External Temperature	Appendix C

Accessories

The SmartReader 1 Temperature Logger can be used with ET series temperature probes (refer to Appendix C Thermistor Temperature Probes or any NTC thermistor data). To use an external temperature probe, simply connect the two wires to the terminals marked "**Temp. Sensor**" and activate the external temperature channel. Note that polarity does not matter when connecting thermistor leads. If you are using shielded cable (recommended for cable extensions), terminate the shield wire by connecting it to the lower of the two "**Temp. Sensor**"

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terminals (the *common* terminal).

Other Applications
For information on how you can monitor resistance or switch status with your SmartReader 1, refer to Appendix A Monitoring Resistance and Switch Status.

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1.4 SmartReader 2 Temperature & Humidity Logger

A self-contained "air-quality" logger, the SmartReader 2 can be used easily in a wide variety of applications to collect temperature and relative humidity data.

Figure 2-1: SmartReader 2

1.4.1 Description

The SmartReader 2 includes an on-board thermistor temperature sensor and a plug-in RH Sensor plus two input channels for an optional remote temperature and relative humidity probe.

How It Works
The relative humidity sensor in the SmartReader 2 is a processed plastic wafer. This wafer is actually a laser-trimmed, capacitive thin-film relative humidity sensor.

Changes in relative humidity cause the surface capacitance of the polymer film to vary. The SmartReader 2 gauges this capacitance by passing a small electric current through it and measuring the relative voltage drop. Because the response of the sensor is temperature dependent, a temperature reading is always taken at the same time as the humidity reading. That way, when the logger's information is backed up into your computer, TrendReader software can automatically factor in the right compensation values when it calculates the percentage of Relative Humidity (in % RH). The result is an accurate set of automatically-generated and temperature-compensated relative humidity readings.

1.4.2 Setup

Make sure to enable each channel you want to use. If you are not using a channel, disable it to save logger memory.

Channel	Description	Equation
0	Internal Temperature	45
1	Internal Relative Humidity	71

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2	External Temperature	Appendix C
3	External Relative Humidity	71

NOTE: When you activate either RH channel, you must also enable its corresponding temperature channel, as well, in order to temperature compensate the RH sensors.

Precautions
The SmartReader 2's RH Sensor is designed for long-term trouble-free performance, but there are a few precautions to keep in mind to maximize the benefit it can give you.

- Never expose the sensor to organic solvents or ionic-laden liquids. Any chemical compound that attracts polymers may affect the sensor.
- The RH sensor is particularly susceptible to contamination by sulfur gases and sulfur compounds. **DO NOT SMOKE NEAR THE LOGGER!**
- Always return your SmartReader 2 to a resealable plastic bag during non-use to maximize the in-calibration life of the RH sensor.

1.4.3 Accessories

You can obtain replacement RH Sensors, remote temperature probes, temperature and relative humidity probes for use with your SmartReader 2.

ET Series Temperature Sensors
The ET Series Temperature sensors are thermistor probes that can be used easily with your SmartReader 2 for remote temperature measurements. The advantage of these probes is that they can be used for a wider range of temperatures, are more versatile (they can be used to record fluid temperatures) and their small size permits them to be easily inserted in hard-to-get-at-locations (such as in ductwork or under pipe insulation).

To use an ET Temperature probe with your SmartReader 2 you must first enable the logger's external temperature channel. Connect the remote temperature probe by connecting one wire (of the two-wire probe) to the channel marked **Temperature** and the other wire to the terminal marked **Common.** For more information on ET series thermistor probes, refer to Appendix C Thermistor Temperature Probes.

EH-020A Temperature and Relative Humidity Probe
The EH-020A is a four-wire probe with a temperature and relative humidity sensor. For field-mounting convenience, it also has a magnetic backing and a security eyelet. To use the EH-020A with your SmartReader 2, you must enable the logger's external temperature and humidity channels. To connect the EH-020A probe to your SmartReader 2, follow instruction

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notes packed with each RH probe set -- see Figure 2-2.

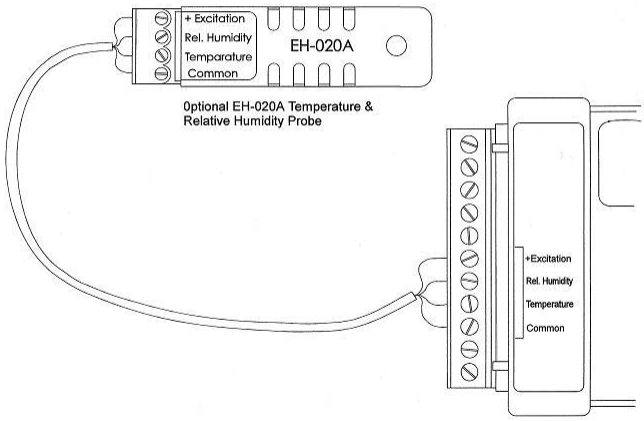

Figure 2-2: Connecting the EH-020A Temperature and RH Probe

The EH-020A is applicable for measurements between -20 and 40°C (-4 and 104°F) and 10 to 90% RH.

> **NOTE:** The EH-020A probe is compatible with loggers that have serial numbers above 20,000 only.

The accurate measurement of temperature and humidity depends primarily on the information supplied by a particular sensor. SmartReader 2 data loggers use temperature and humidity sensors with rugged qualities designed for minimal or no maintenance (under normal operating conditions).

The SmartReader 2's on-board thermistor is chemically stable and not significantly affected by aging. It will typically drift less than 0.1°C over a period of several years. The relative humidity sensor, although subject to accuracy degradation when exposed to contaminants and/or extreme environmental conditions, will drift typically less than 1% per year (under clean conditions). You should check your RH sensor periodically and, if necessary, recalibrate or replace it.

1.4.4 Troubleshooting

If you are getting what appear to be wrong readings, consider the following before recalibrating the sensors. Sensors sample the atmosphere (or medium) only in the immediate vicinity of the sensors themselves. The physical state of the atmosphere and its degree of uniformity and turbulence will limit the validity of a measurement at some distance from the sensor. This becomes especially apparent for the measurement of ambient temperature and relative humidity.

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In a room, temperature and RH levels may vary dramatically from location to location. Such factors as air stratification, drafts, and proximity to heat or humidity sources (people, equipment, moisture, solar gain, etc.) can contribute to a wide variance in conditions even within a small, confined area. The individual sensors associated with your SmartReader 2 measure and record temperature and RH only in one location. They do not, in any way, represent an overall reading.

If you decide to check the calibration of your SmartReader 2 RH Module using a Sling Psychrometer, keep in mind the following:

- Any instrument that requires a person to be present at, or in very close proximity to the RH sensor in order to get a reading, will have a measurement error introduced to it. That is because the body readily gives off heat and moisture that is especially noticeable at lower RH levels.

- The time taken between slinging the psychrometer and reading it can exhibit several degrees of inaccuracy in the wet bulb reading. Air currents around the body, whether it is slung in the shade of a building or in sunlight, not knowing how to tie the wet sock, its condition, and the purity of water used, all contribute to error. In addition, interpolating the data from a psychrometric chart can add another 2 to 4% to the accumulative error.

1.4.5 Relative Humidity Calibration

Each relative humidity sensor has been individually calibrated in an environmental chamber with standards traceable to the National Institute of Standards and Technology (NIST).

The SmartReader 2 and the EH-020A probe are supplied with a calibration certificate which provides calibration values. These calibration values must be entered in and stored in the logger during initial setup. If your RH sensor is out of calibration, you can simply replace it with a new one.

> **NOTE:** A straight replacement of the RH sensor will introduce an additional +2% tolerance on the RH accuracy. Calibration of the RH channel with the new RH sensor is recommended.

In the event that you wish to confirm the RH calibration of your sensor, you can perform your own field test. Refer to Appendix B Temperature and Relative Humidity Calibrations for more information on RH testing.

Interchangeable replacement RH sensors for loggers are available through your dealer. For best accuracy, it is recommended these be calibrated together with the logger - consult your ACR representative for price and availability of this service. Replacement EH-020A modules which are pre-calibrated are available through your dealer.

1.4.6 Specifications

Temperature Sensor (internal)

Type:	NTC Thermistor - 10,000 Ohm at 25°C (77°F)
Range:	-40 to 70°C (-40 to 158°F)
Accuracy:	+/- 0.2°C over the range of 0 to 70°C

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(+/- 0.3°F over the range of 32 to 158°F)

Resolution: 0.4°C (0.7°F) at 25°F; better than 1°C (1.8°F) between -25 and 70°C (-13 and 158°F); better than 2.0°C (3.6°F) between -40 and -25°C (-40°F and -13°F)

Relative Humidity Sensor & EH-020A

Type: Capacitive thin polymer film

Range: 0 to 95% (non-condensing)

Accuracy: ±4% from 10 to 90% RH (-20 to 40°C [-4 to 104°F])

Resolution: Better than 0.4% RH between 25 and 60% RH at 25°C (77°F)

Response Time: Adequate ventilation reduces the response time which is approximately 5 minutes in still air.

Environmental Conditions: The RH sensor is relatively immune to chemical contamination but when exposed to extreme environmental conditions, accuracy degradation could result. For long-term stability and reliable readings, the sensor should not be subjected to liquid immersion or exposed to high concentrations of organic solvents, corrosive agents, sulfur gases and strong acids or bases. Dust settling on the sensor surface will not affect sensor performance except possibly to decrease the speed of response.

Chemical Tolerances: Limits for different chemical groups

1. Organic solvents typically 1,000...10,000 ppm
2. Corrosive agents (strong acids S02, H2SO4, Cl2, HCl, H2S etc.) typically 1...10 ppm
3. Weak acids typically 100...1,000 ppm
4. Bases typically 10,000...100,000 ppm

Specifications are subject to change without notice.

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1.5 SmartReader 3 Electric Current and Temperature Logger

The SmartReader 3 is a versatile equipment performance logger. It can simultaneously monitor and record up to three external channels of AC current without having to interrupt circuitry under test.

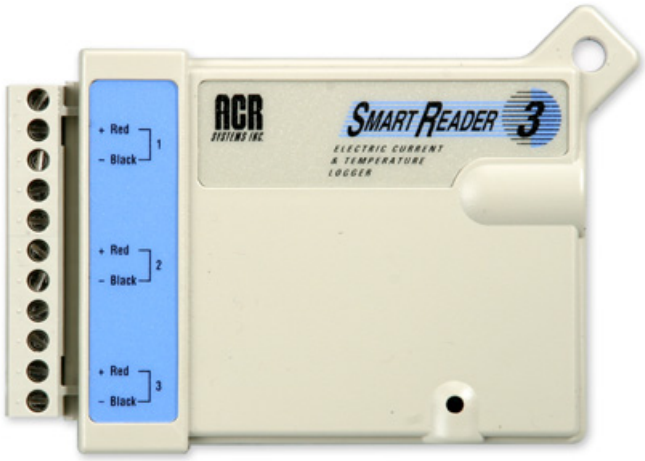

Figure 3-1: SmartReader 3

1.5.1 Description

The SmartReader 3 has three current monitoring channels and one internal thermistor temperature channel. The current-monitoring channels are used with external clamp-on probes to measure and record alternating current.

The SmartReader 3 is compatible with the following current probes from Amprobe Instruments:

- A60FL and A70FL probes for 60Hz power systems
- A65FL and A75FL for 50Hz power systems

Use of these probes allows you to measure alternating current of conductors without the need for breaking circuitry. For information on current ranges and resolutions refer to the Specifications in this chapter.

How It Works

The SmartReader 3 measures electric current through external current probes. Each current probe is a transformer with its internal coil serving as the secondary winding and the current-carrying conductor being measured serving as the primary winding. The output of the probe (which is the input to the SmartReader 3) is conditioned through internal circuitry. The probe produces an output of approximately 260 microamps full scale for each range available on the current probe. Readings from the current probe are scaled into amperage units through equations (in TrendReader software) that match the current probe and its range setting.

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1.5.2 Setup and Use

The basic procedure for setting up your SmartReader 3 is as follows:

1. Connect one or more current probes, specified above, to the current channel inputs on your SmartReader 3. Make sure to observe polarity when making connections. Connect the current probe's red (**+**) wire to the channel's "**+ Red**" input. Connect the current probe's black wire to the channel's "**- Black**" input.

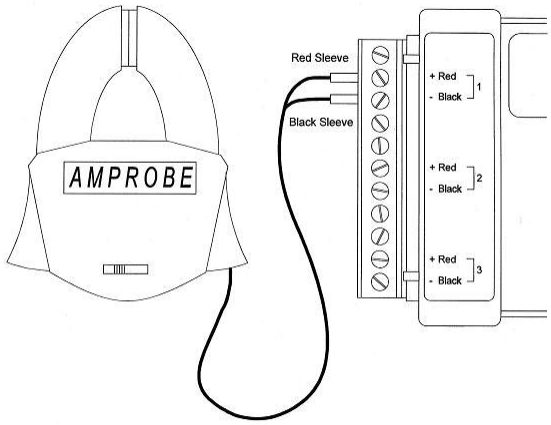

Figure 3-2: Connecting an external current probe

2. Adjust the range setting on the current probe(s) to suit your application. A good way to verify a conductor's maximum range is to check the circuit breaker or fuse rating. Set the range on your current probe to suit. Since the probes do not give predictable readings below 10%, always choose the lowest range possible that will encompass the full range of data you want to record.

3. Make sure to enable each channel you want to use. If you are not using a channel, disable it to save logger memory.

Channel	Description	Equation
0	Internal Temperature	45
1	Current 1	as below
2	Current 2	as below
3	Current 3	as below

	A60FL / A65FL	
Switch	**Range**	**Equation**
5	0.5 to 5 A	63

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25	2.5 to 25 A	64
100	10 to 100 A	65
250	25 to 250 A	66

	A70FL / A75FL	
Switch	**Range**	**Equation**
10	1 to 10 A	67
50	5 to 50 A	68
250	25 to 250 A	69
500	50 to 500 A	70

Precautions

1. **DANGER: High voltage may be present!** Do not clamp a current probe around a conductor without the logger connected to it. This avoids sparking and prevents the connectors from prematurely deteriorating.

2. The SmartReader 3 is to be used only with approved current probes from Amprobe Instruments (A60FL, A70FL, A65FL, and A75FL). These probes provide low voltage DC current in proportion to the signal being measured. DO NOT use any other probe unless approved by ACR in writing.

3. The SmartReader 3 can record current in accordance with the ranges available on the A60FL, A65FL, A70FL and A75FL probes. Always make sure the current you will be recording will fall into the appropriate range you set on the current probe.

1.5.3 Current Probes and Accessories

Each SmartReader 3 has three pairs of input connections for use with the Current Probes from Amprobe Instruments. These clamps can be used with a number of accessories to fit most typical applications.

Low Currents

To log very low currents (such as monitoring the operation of electrical appliances), the probe can be used with a Line Splitter. The Amprobe A47L Energizer multiplies the signal to the logger by ten times over a range of 0.1 to 15A. It also allows effectively splitting of a two-line conductor, allowing measurements without the need to enter electrical panels or junction boxes.

For European applications, Amprobe's model A47CL is available with screw-in European round prongs, two extra British-type prongs and a British fuse plug adapter. Contact your local ACR representative for pricing and delivery of this product.

High Currents

You can monitor current ranges higher than those available on a standard probe by using it with an additional transformer. For this purpose Amprobe Instruments has available their Amptran® CT50-2 a 50-to-1 transformer (to monitor currents up to 3000 amps). Contact your

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ACR representative for pricing and availability on this probe.

Extending Probe Lead Lengths
The lead length of the Amprobe probes can be extended by splicing in up to 225m (750 ft.) of 2-conductor 18-gauge copper wire.

1.5.4 Specifications

Output Current:	260 μA DC full scale into 400 ohms.
Lead Length:	1.5m (5ft)
Accuracy:	±4% FS above 10% of range.
Ranges:	A60FL / A65FL: 5, 25, 100, 250A A70FL / A75FL: 10, 50, 250, 500A
Maximum Voltage:	1500 Vrms secondary to core 3000 Vrms (4200 Vpeak) lamination to case

1.5.5 Troubleshooting

The SmartReader 3 seems to give wrong readings. What is wrong?

- If your graphs seem incorrect, check the equation number assigned to the graph file. This equation number **must** correspond to the model number and setting of the current probe used. Refer to Setup in this chapter for a table of equations to use with the various current probes and settings.

- If your Realtime readings seem incorrect, check the equation number assigned to the logger channel you are viewing. Make sure it corresponds to the model number and active setting of the current probe you are using.

- If your equation numbers are correctly assigned and you are still getting incorrect readings, it may be because you are measuring currents below 10% of the range. To correct this, make sure the range setting on the probe is at the lowest possible range that will encompass the readings you are interested in. For example, do not use the 250 amp range for recording currents below 25 amps. However, if the readings fluctuate widely (for example, the difference between the day and night time power consumption), it may be necessary to attach two probes - one on a high range and the other on a low range.

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1.6 SmartReader 4 Pressure & Temperature Logger

The SmartReader 4 is a general purpose logger that can monitor pressure, temperature and relative humidity.

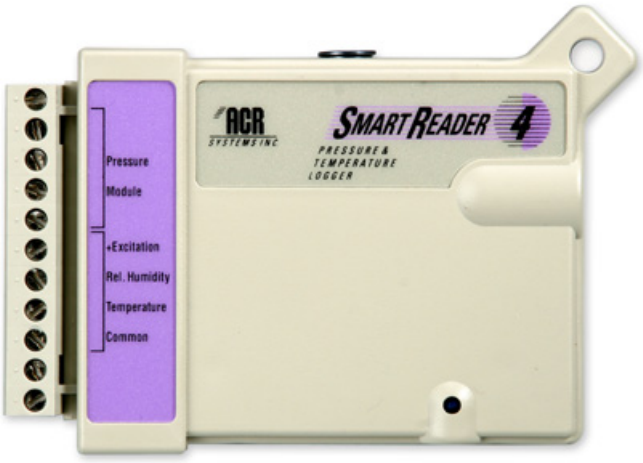

Figure 4-1: SmartReader 4

1.6.1 Description

The SmartReader 4 is a five-channel logger designed to work with external pressure, temperature, and relative humidity sensors that you can order separately. The plug-in Pressure Module is available in several different ranges. The internal RH sensor allows you to record relative humidity. The EH-020A Temperature & Relative Humidity probe allows you to do remote temperature and RH sensing.

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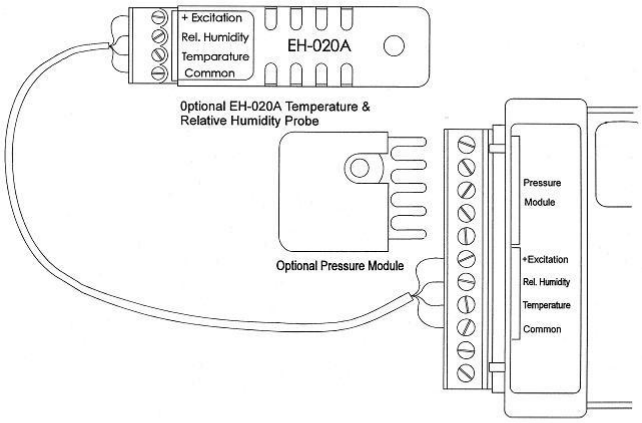

Figure 4-2: SmartReader 4 Accessories

1.6.2 Setup

Using the Pressure Modules

1. If you are going to measure pressure, you will need a Pressure Module, a length of plastic tubing and the appropriate fittings to tie into the system or equipment you intend to monitor.

2. To connect the Pressure Module, plug it into the five terminals as shown in Figure 4-2. Make sure it is properly plugged in and secured to the terminal block.

3. Use TrendReader software to enable the pressure channel. Then assign the correct pressure equation for the model of Pressure Module you are using. If you want to switch from one Pressure Module to another, change the equation number assigned to the pressure channel.

Module	Range	Type	Resolution	Equation
PM-005-G	0 to 5 PSI (30 kPa)	Gauge	0.03 PSI (0.2 kPa)	20
PM-030-G	0 to 30 PSI (200 kPa)	Gauge	0.15 PSI (1.0 kPa)	8
PM-100-G	0 to 100 PSI (700 kPa)	Gauge	0.5 PSI (3.5 kPa)	22
PM-150-G	0 to 150 PSI (1000 kPa)	Gauge	0.5 PSI (3.5 kPa)	22
PM-030-A	0 to 30 PSI (200 kPa)	Absolute	0.15 PSI (1.0 kPa)	8
PM-100-A	0 to 100 PSI (700 kPa)	Absolute	0.5 PSI (3.5 kPa)	22

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Pressure Measurement Precautions
The SmartReader 4 is designed for long-term, trouble-free performance but there are a few precautions to keep in mind to maximize the benefit it can give you.

- The pressure sensor in the Pressure Module is compatible with non-corrosive gases and dry air. It is **not** to be used for liquid pressure measurements.

- Always try to make your pressure connections separate from the Pressure Module and logger. To do this, leave a short length of tubing continually attached to the input port. Stressing the input connection may cause it to break, resulting in erroneous readings.

EH-020A Remote Temperature & RH Probe
The EH-020A is a four-wire probe with a temperature and relative humidity sensor. For field-mounting convenience, it also has a magnetic backing and a security eyelet. To use the EH-020A with your SmartReader 4, you must enable the logger's external temperature and humidity channels. To connect the EH-020A probe to your SmartReader 4, follow instruction notes packed with each RH probe set -- see Figure 4-2.

Remote Thermistor Temperature Probe
You can monitor temperatures remotely using an ET temperature probe with your SmartReader 4 by connecting the probe's two wires to the **Temperature** and **Common** terminals. Make sure the External Temperature channel is activated and proper equation is selected.

1.6.3 Pressure Calibration

The pressure sensor (in the Pressure Module), although subject to accuracy degradation when exposed to contaminants and/or extreme environmental conditions, will drift typically less than 1%/year (under clean conditions). You should check your SmartReader 4 periodically and, if necessary, recalibrate or replace the Pressure Module. In the event that you wish to confirm the pressure calibration of your SmartReader 4 Logger, you can perform your own calibration using the adjustment provisions explained in TrendReader software.

The recommended method of calibration is to use a pneumatic pressure calibrator with a preferred accuracy of at least 0.1% full scale. All the pressure modules can be calibrated with an offset and a gain up to ±5% of full scale.

Procedure
The Low calibration value is a zero adjustment and the Mid calibration value compensates for span. The calibration procedure is as follows:

1. Activate the pressure and temperature monitoring channels of your SmartReader 4 if not already enabled.

2. Set all calibration values to Zero.

3. Ensure that the correct equation is selected.

4. With the input port unconnected (open to ambient), Record the pressure reading you see

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as (A). The reading should be close to zero if you are using a gauge sensor, or close to ambient pressure (AP) if you are using an absolute sensor.

5. Enter a Low calibration value using:
   - For absolute sensor: -(A-AP)*100/FS
   - For gage sensor: -(A*100/FS)

   Where:
   A = The Realtime reading (in PSI) observed in previous step.
   AP = Ambient pressure.
   FS = Full scale rating of the logger.

   NOTE: Make sure you enter the Low calibration value before going to the next step.

7. Connect the input port of the logger to the calibrator, ensuring all connections are completely airtight.

8. Adjust the calibrator to produce a test pressure equal to the full scale (FS) range of the logger. Record the pressure reading you see as (B).

9. Enter a Mid calibration value using:
   - (FS/B-1)*100

   Where:
   FS = Full scale range of the logger.
   B = The real-time reading

10. Save the calibration changes to the logger.

1.6.4 Specifications

The following specifications apply to the pressure sensors used in the SmartReader 4:

Type:	Silicon piezoresistive strain gauge
Max. Pressure:	4 x FS
Media:	Noncorrosive gases and dry air
Temp. Range:	
Operating:	-40 to 70°C (-40 to 158°F)
Compensated:	0 to 70°C (32 to 158°F)
Accuracy:	0.5% FS @ 25°C (77°F)
Thermal:	over Compensated Range
5 PSI	±1.5% FS
30 PSI	±0.5% FS
100 PSI	±0.5% FS
Linearity:	best fit straight line
5 PSI	±0.25% FS
30 PSI	±0.1% FS
100 PSI	±0.1% FS

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1.7 SmartReader 5 Thermocouple Logger

The SmartReader 5 Thermocouple Logger can monitor and record temperatures from type J, K, T, or S type thermocouples.

Figure 5-1: SmartReader 5

1.7.1 Description

The SmartReader 5 has two external thermocouple temperature channels and one internal thermistor temperature channel. There are two different temperature ranges:

- Channel 1 (Low) is suited for use over a relatively narrow temperature range. It provides the best resolution readings.
- Channel 2 (High) is useful over a much wider temperature range thus offering greater application flexibility. Resolution is coarser using this channel.

For information on temperature ranges and resolutions applicable for the different types of thermocouples and channels you want to use, refer to the Specifications section.

1.7.2 Setup and Use

The internal thermistor temperature channel for the SmartReader 5 is used to simulate a reference junction for the thermocouples -- it must always be enabled.

1. Connect a J, K, T, or S type thermocouple to one or both channels. Make sure that you observe polarity when making connections. To do this, connect a thermocouple's negative wire (usually red) to the "**-**" terminal of the channel you want to use. Connect the other (positive) wire to the "**+**" terminal. The following table lists the ANSI color code for the thermocouple wires:

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Thermocouple Type	Positive (+) Wire	Negative (-) Wire
J	White	Red
K	Yellow	Red
T	Blue	Red
S	Black	Red

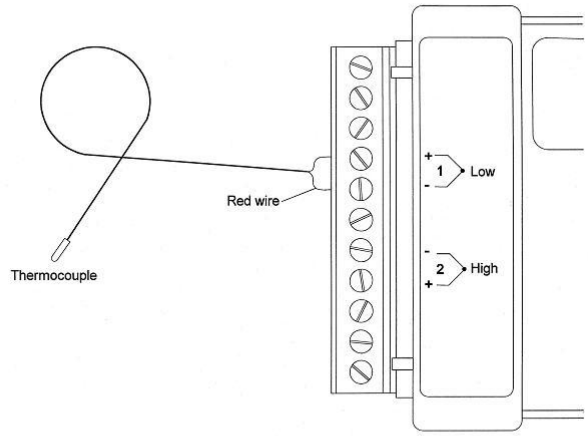

Figure 5-2: SmartReader 5 with a Thermocouple

2. Connect the logger to your computer and run TrendReader. Select the equation number for each active thermocouple channel (refer to the Specifications section.)

3. Check that you have the thermocouple's polarity correct by warming its tip. You will see the Realtime temperature reading increase if the wires are connected correctly. If the temperature decreases, reverse the connections.

   NOTE: The inputs are not isolated from each other (they use the same common "-" terminal internally). This means that the thermocouple tips cannot be touching each other. If they are touching or are fastened to a conducting surface like a metal frame, some looping can occur and the readings may fluctuate. They must be insulated or prevented from making contact with each other electrically. Do not use grounded thermocouples.

1.7.3 Specifications

Accuracy: ±1% of range + resolution

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Type **J** Thermocouple Inputs

Thermocouple	Equation	Range	Resolution
1 (Narrow)	49	-20 to 190°C (0 to 370°F)	1.4°C (2.5°F)
2 (Wide)	50	-50 to 600°C (-55 to 1100°F)	5°C (9°F)

Type **K** Thermocouple Inputs

Thermocouple	Equation	Range	Resolution
1 (Narrow)	51	-25 to 230°C (-10 to 440°F)	1.7°C (3°F)
2 (Wide)	52	-100 to 900°C (-145 to 1650°F)	6.7°C (12°F)

Type **S** Thermocouple Inputs

Thermocouple	Equation	Range	Resolution
1 (Narrow)	73	0 to 960°C (32 to 1750°F)	7°C (12.6°F)
2 (Wide)	74	0 to 1760°C (32 to 3200°F)	23°C (41.5°F)

Type **T** Thermocouple Inputs

Thermocouple	Equation	Range	Resolution
1 (Narrow)	53	-35 to 200°C (-30 to 390°F)	1.7°C (3°F)
2 (Wide)	54	-200 to 400°C (-325 to 750°F)	6.7°C (12°F)

Specifications are subject to change without notice.

1.7.4 Calibration

Low, Mid and High Calibration Values

The Low calibration value compensates for offset while Mid compensates for span. These values are set at the factory using an accurate millivolt reference. The following procedure may be used if you want to calibrate each channel to a specific piece of thermocouple wire:

1. Change the equation number of the channel you want to calibrate to 38, and replace any previous Low, Mid and High calibration values with zero (0). Make sure you have

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selected Byte Count data units.

2. Short the "**+**" and "**-**" terminals of the channel with a piece of wire. Observe the Realtime value for the channel.

3. Enter a Low calibration value of 50 - R, where R = *the Realtime value observed in the previous step*.

4. Change the equation number to the correct one for your thermocouple type and connect the highest possible temperature reference to the channel. Make sure you have selected Celsius temperature units. Observe the Realtime values for the thermocouple channel and the internal temperature channel (Channel 0.)

5. Calculate the Mid calibration value using this formula:
   100 x ((A - C) - (B - C)) / (A - C)

   where:
   A = *thermocouple channel reading*
   B = *high reference temperature*
   C = *internal temperature channel reading*

   For example, if your thermocouple channel reads 502°C at a high reference of 500°C, and the internal temperature channel reads 25°C, the Mid calibration value is equal to:
   100 x ((502 - 25) - (500 - 25)) / (502 - 25) = 0.419

6. Enter the Mid calibration value obtained in the previous step and save the setup to the logger.

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1.8 SmartReader 6 Thermocouple Logger

The SmartReader 6 Thermocouple Logger can monitor and record temperatures from type J, K, T, or S type thermocouples.

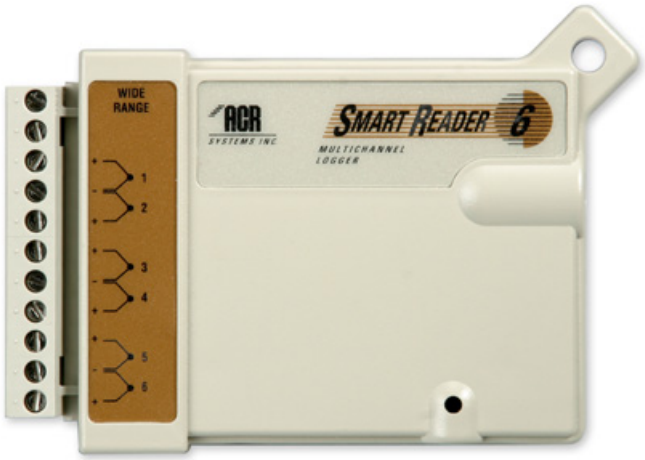

Figure 6-1: SmartReader 6

1.8.1 Description

The SmartReader 6 has six external thermocouple temperature channels and one internal thermistor temperature channel for a cold-junction reference.

There are two basic models of SmartReader 6:

- SmartReader 6 N has all channels set for use over a narrow temperature range.
- SmartReader 6 W has all channels set for use over a wider temperature range but resolution is coarse.

For information on temperature ranges and resolution for the different types of thermocouple, refer to the Specifications section.

1.8.2 Setup and Use

The internal thermistor temperature channel for the SmartReader 6 is used to simulate a reference junction for the thermocouples -- it must always be enabled.

1. Connect a J, K, T, or S type thermocouple to one or more channels. Make sure that you observe polarity when making connections. To do this, connect the thermocouple's negative wire (usually red) to the "**-**" terminal of the channel you want to use. Connect the other (positive) wire to the "**+**" terminal. The following table lists the ANSI color code for thermocouple wires:

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Thermocouple Type	Positive (+) Wire	Negative (-) Wire
J	White	Red
K	Yellow	Red
T	Blue	Red
S	Black	Red

2. Connect the logger to your computer and run TrendReader. Select the equation number for each active thermocouple channel (refer to the Specifications section).

3. Check that you have the thermocouple's polarity correct by warming its tip. You will see the Realtime temperature reading increase if the wires are connected correctly. If the temperature decreases, reverse the connections.

   NOTE: The inputs are not isolated from each other (they use the same common "-" terminal internally). This means that the thermocouple tips cannot be touching each other. If they are touching or are fastened to a conducting surface like a metal frame, some looping can occur and the readings may fluctuate. They must be insulated or prevented from making contact with each other electrically. Do not use grounded thermocouples.

1.8.3 Specifications

Accuracy: ±1% of range + resolution

Type **J** Thermocouple Inputs

Thermocouple	Equation	Range	Resolution
1 (Narrow)	49	-20 to 190°C (0 to 370°F)	1.4°C (2.5°F)
2 (Wide)	50	-50 to 600°C (-55 to 1100°F)	5°C (9°F)

Type **K** Thermocouple Inputs

Thermocouple	Equation	Range	Resolution
1 (Narrow)	51	-25 to 230°C (-10 to 440°F)	1.7°C (3°F)
2 (Wide)	52	-100 to 900°C (-145 to 1650°F)	6.7°C (12°F)

Type **S** Thermocouple Inputs

Thermocouple	Equation	Range	Resolution
1 (Narrow)	73	0 to 960°C	7°C (12.6°F)

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		(32 to 1750°F)	
2 (Wide)	74	0 to 1760°C (32 to 3200°F)	23°C (41.5°F)

Type **T** Thermocouple Inputs

Thermocouple	Equation	Range	Resolution
1 (Narrow)	53	-35 to 200°C (-30 to 390°F)	1.7°C (3°F)
2 (Wide)	54	-200 to 400°C (-325 to 750°F)	6.7°C (12°F)

Specifications are subject to change without notice.

1.8.4 Calibration

Low and Mid Calibration Values

The Low calibration value compensates for offset while Mid compensates for span. These values are set at the factory using an accurate millivolt reference. The following procedure may be used if you want to calibrate each channel to a specific piece of thermocouple wire:

1. Change the equation number of the channel you want to calibrate to 38, and replace any previous Low and Mid calibration values with zero (0). Make sure you have selected Byte Count data units.

2. Short the "**+**" and "**-**" terminals of the channel with a piece of wire. Observe the Realtime value for the channel.

3. Enter a Low calibration value of 50 - R, where R = *the Realtime value observed in the previous step*.

4. Change the equation number to the correct one for your thermocouple type and connect the highest possible temperature reference to the channel. Make sure you have selected Celsius temperature units. Observe the Realtime values for the thermocouple channel and the internal temperature channel (Channel 0.)

5. Calculate the Mid calibration value using this formula:
   100 x ((A - C) - (B - C)) / (A - C)

   where:
   A = *thermocouple channel reading*
   B = *high reference temperature*
   C = *internal temperature channel reading*

   For example, if your thermocouple channel reads 502°C at a high reference of 500°C, and the internal temperature channel reads 25°C, the Mid calibration value is equal to:
   100 x ((502 - 25) - (500 - 25)) / (502 - 25) = 0.419

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6. Enter the Mid calibration value obtained in the previous step and save the setup to the logger.

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1.9 SmartReader 7 Process Signal Logger

A multi-channel, multi-purpose logger, the SmartReader 7 provides a versatile means of logging a wide variety of measurement parameters. It features seven input channels configured for easy interface with common transducer and transmitter outputs.

Figure 7-1: SmartReader 7

1.9.1 Description

The SmartReader 7 can measure and record data from five separate channels of analog DC voltage covering the ranges of 0 to 200 millivolts, 0 to 2.5 volts 0 to 5 volts, and 0 to 10 volts and from two DC current channels covering the range of 0 to 25 milliamps.

How the SmartReader 7 Works

The 200 mV channel uses a pre-amplifier to magnify the signal ten times for maximum resolution by the A/D converter. The 5 and 10 volt channels are converted to a 0 to 2.5 volt signal by internal resistive divider circuits. All digital values are converted to their proper engineering units by equations in TrendReader software.

Current flow through a loop is logged by measuring the voltage drop across an internal 100 ohm input resistor. This voltage drop is accurately gauged by comparing it to a highly-stable voltage reference before conversion to a digital value by the A/D converter. The digital values are then processed into engineering units by an equation in TrendReader software.

1.9.2 Setup

This section provides guidelines to follow to get you started with your SmartReader 7.

1. The first step in using your SmartReader 7 is to decide what information, or parameters, you want to log. For example, you may simply wish to replace an existing hard-wired 4-20 mA chart recorder or, instead, monitor from a special multiple-transducer circuit that

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you have assembled (see the Applications section).

2. Determine what sensors, transducers, or transmitters you need to do the job (if not already present). Compatible transducers for monitoring temperature, humidity, pressure, speed, and many more variables are available through a wide variety of vendors (see Selecting Transducers and Transmitters).

3. Modify the channels, externally (using resistors), if required, for maximum resolution (see Customizing Input Ranges).

4. Write a Custom Equation to convert the internal A/D converter readings from the transducer or circuit you want to monitor into the proper engineering units required (for example, a 4-20mA signal representing 0 to 10,000 l/min). For help in writing these equations refer to the TrendReader guide.

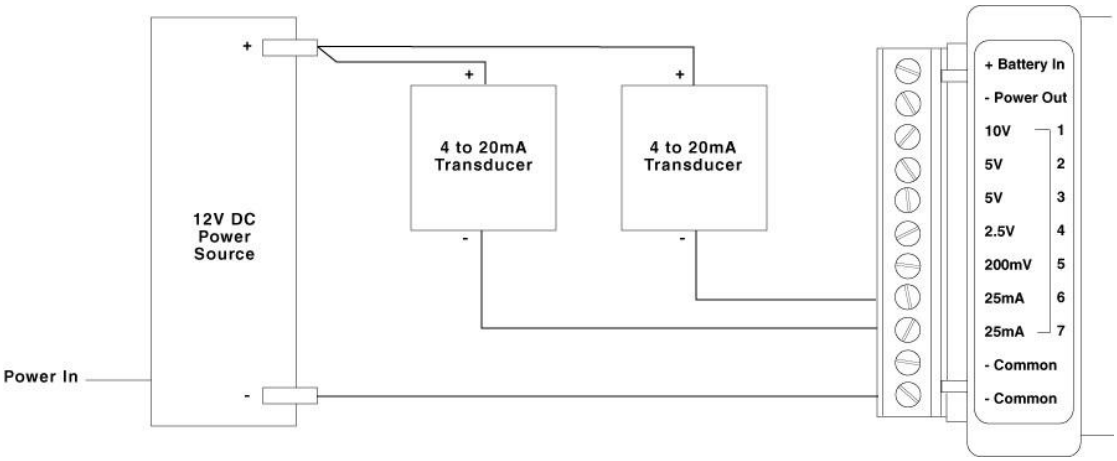

Figure 7-2: Using Transducers with a Power Supply

5. Decide how you are going to power your transducers (if required). You can either use a standard power supply, creating a circuit like that shown in Figure 7-2 or use batteries, producing your own self-contained logging assembly (Figure 7-3). For this application

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you must activate the battery switch (see External Battery Control).

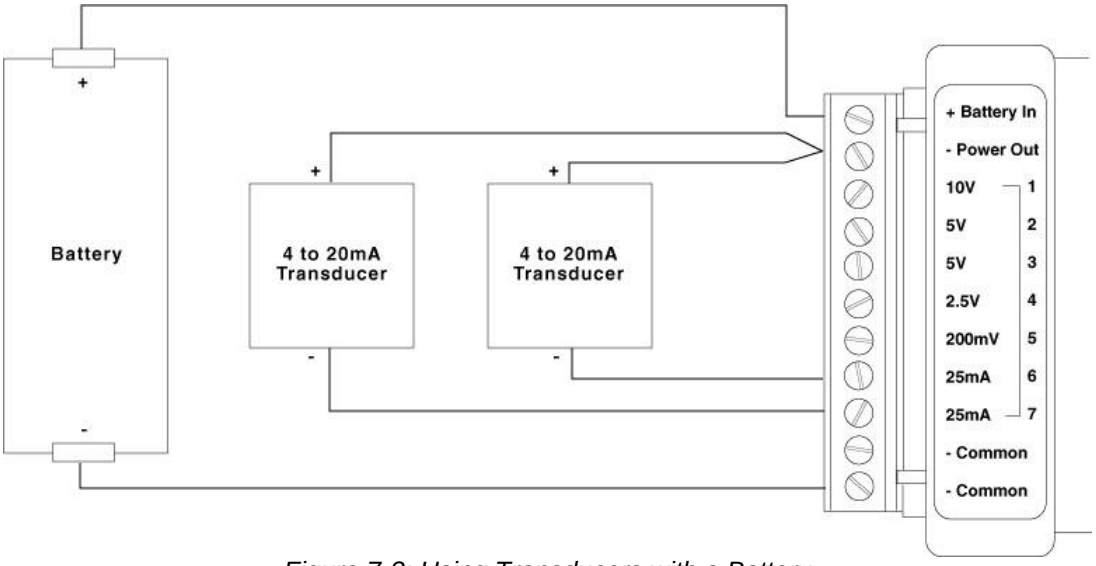

Figure 7-3: Using Transducers with a Battery

6. Connect your transducers or transmitters and check operation by observing the Realtime values displayed by TrendReader software. If you can, try to exercise your transducers (make them change their output) to ensure that everything works. If it does, then you are ready to place your assembly in the field to start logging.

Avoiding Ground Loop Problems

Take special care to avoid ground loop problems when you use your SmartReader 7. A ground loop can occur when there is more than one path to ground in your logger-transducer circuit. Ground loops can damage your SmartReader 7 as well as your transducers. To avoid ground loop problems in your SmartReader 7 circuit:

1. Do not use more than one grounded power supply to excite your transducers.

2. Do not connect your logger to your computer for Realtime readings unless:

   - your computer is battery-operated (i.e. not grounded); or
   - your transducer power supply is not grounded.

If you must use more than one grounded power supply in your SmartReader 7 circuit, *each* transducer you use must be isolated. If you must use non-isolated transducers, then you must use a Signal Repeater/Loop Isolator between the transducer output and the SmartReader 7 input.

Wiring Notes and Considerations

1. The SmartReader 7 has two common inputs (labeled " **- Common**"). These are not isolated from each other and can be used as the negative "**-**" connection for the power supply (or battery) and any of the transducers being logged by the SmartReader 7.

2. The 2.5V and 200mV channels "float" when no connections are made to them. They can

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thus be expected to read a positive voltage when left unconnected. When connected, however, they will read the correct input voltage.

3. The 25mA channels read positive current only. *Make sure to observe polarity*. If you are using both channels simultaneously, ensure that both 4-20mA transmitters operate with their negative (-) terminals tied together.

1.9.3 Choosing Input Channels

To choose which of the SmartReader 7's seven external input channels is best for your particular applications, an understanding of *resolution* is required.

Maximizing Resolution

The resolution of your SmartReader 7 Logger is eight bits. This means that it can resolve analog signals, with a defined range, to 256 discrete steps (2 to the power of 8). When logging from the 2.5V channel, for example, the SmartReader 7 will record digital values in increments of 2.5 volts divided by 256, or approximately 10 millivolts.

Resolution is usually not a significant factor until you have logging applications that will produce input signals far less than that of the range of the logger's channel itself.

The 2.5V channel will have a resolution of 0.4% over a range of 0 to 2.5 volts (.01/2.5 x 100) which should be more than adequate for most applications. If, however, you are intending to measure signals ranging from 50 to 150 millivolts (with the same 2.5V channel), resolution will be much coarser (10%). By switching the 50 to 150 millivolt input to the 200mV channel, resolution can be improved to approximately 1%.

Choosing Input Channels

It is important to maximize resolution when measuring and recording from the SmartReader 7's current and voltage channels. Usually you can do this simply by choosing the channels that match or approximate the input signals you will be using. The table below lists several possible input signal ranges and the recommended channels to use. It also lists alternative channels that can be used for additional simultaneous monitoring capability. These alternative channels will, however, require the addition of external resistors (see Customizing Input Ranges).

Range	Standard	Alternative
0 to 500 mv	2.5V	200mV
0 to 1.0 volt	2.5V	200mV
0 to 2.0 volts	2.5V	200mV
0 to 3.0 volts	5V	2.5V, 200mV
0 to 6.0 volts	10V	5V, 2.5V, 200mV
0 to 20 volts	N / A	10V, 5V, 2.5V, 200mV
0 to 2.0 mA	25mA	200mV
4 to 20 mA	25mA	2.5V, 200mV
0 to 50 mA	N / A	25mA, 5V

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0 to 100 mA	N / A	25mA, 10V

In the above table, the *Range* column lists examples of input signals that you may wish to monitor using your SmartReader 7. The *Standard* column lists the channel you would normally choose to monitor that particular signal. The *Alternative* column lists other channels that can be used to monitor the same input signals. In most cases, these channels will need to be fitted with external resistors.

Non-Standard Ranges

You may want to use a special transducer or tie into an existing process signal loop that does not match the SmartReader 7's standard input ranges. The following step-by-step procedure will help you choose which channel is best:

1. Determine the maximum output signal (**M**) and the zero offset signal (**Z**) of the transmitter or circuit you wish to tie into. For example, a transducer with a specified range of 1 to 6 volts DC will have a maximum output signal of 6 volts and a zero offset signal of **1 volt**. A 4 to 20 milliamp transmitter will have a maximum output signal of **20 mA** and a zero offset signal of **4 mA**.

2. Determine the transducer's full scale output (F). You can do this simply by subtracting **Z from M**. The full scale output of the 1 to 6 volt transducer is thus **5 volts**. The full scale output of the 4-20mA transmitter is **16 mA**.

3. Compare **M** with the channels available on the SmartReader 7 and choose a channel with an input equal or greater to this value (if available). If no such channel exists, then modify one to suit by referring to the Customizing Input Ranges section.

4. Determine if the resolution (**R**) of the channel you chose in Step #2 will be adequate. You can determine this, in percent, by using the following equation:

   $$R = C * 0.4 / F$$

   Where:
   - C = the input range of the channel you chose to use (in units of either millivolts, volts or milliamps).
   - F = the full scale output of your transducer (M - Z) measured in the same units as for C.
   - R = the resolution expressed in a percentage (%) of full scale output.

   For example, a 0.5 to 2.5 volt transducer connected to the 2.5V channel will be logged with a resolution of **0.5%**. A 4 to 20mA transducer hooked up to the 25mA channel will log with a resolution of **0.6%**.

   Generally, it is good practice to keep resolution to within 1% for most applications. However, you might accept far coarser resolution in some applications and, in others, require far better. You will be able to determine your own requirements after you have become familiar with the results you can expect with different arrangements. If your requirements demand greater resolution than what you calculated, then you should set up your inputs with resistors as described in the Customizing Input Ranges section in this chapter.

5. To find out in what actual steps (**S**) your logger will collect data, first determine the input (**I**) of your transducer or transmitter. You can do this by subtracting the lowest level input

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from the high. A thermocouple transmitter, for example, with a range of -20°C to 600°C will have an input span of **620**° (600-(-20)). A pressure transducer with a range of 0 to 100 psi will have an input span of **100 psi**.

6. To calculate **S**, measured in the same units as the input span (**I**) above, use this equation:

$$S = R * I / 100$$

For example, a 4 to 20mA Relative Humidity transmitter with an input span (**I**) of 90% RH and a calculated resolution (**R**) of 0.6% will record data in steps of **0.54% RH**.

1.9.4 Customizing Input Ranges

The standard input ranges on the SmartReader 7 should be suitable for most process signal applications, but occasionally you may require measurement of non-standard input levels where resolution is a primary concern (see Choosing Input Channels). Ranges can be adapted easily by using either one or two external resistors. TrendReader software has **Equation** functions that can be used to scale the data to the new input levels.

The resistor value that you will require to modify each SmartReader 7 input channel is selected by inserting your special input requirements into a simple equation. The following sections detail these equations and the method of tying in these resistors.

10 Volt Channel

The 10 volt channel can be modified to span higher ranges (greater than 10 volts DC) by adding a single resistor to the "**10V**" terminal shown in Figure 7-4. The value of the resistor (R) can be calculated by the following formula below, based on the desired voltage input range (Ein):

$$R = 4{,}090 \times Ein - 40{,}900$$

For example, if you wish to measure up to 20 volts, the resistor value should be:

$$4{,}090 \times 20 - 40{,}900 = 40{,}900 \text{ ohms}$$

Since you will not always be able to get the exact resistor value that you calculated, you can determine the logger's actual input range by plugging the value of the resistor (R) you obtain back into the equation. For example, if the closest resistor you could obtain was 42k ohms, then the actual voltage input range would be:

$$Ein = (R + 40{,}900) / 4{,}090$$

$$(42{,}000 + 40{,}900) / 4{,}090 = 20.27V$$

This value will be needed when it comes time to create your own custom equation using TrendReader software.

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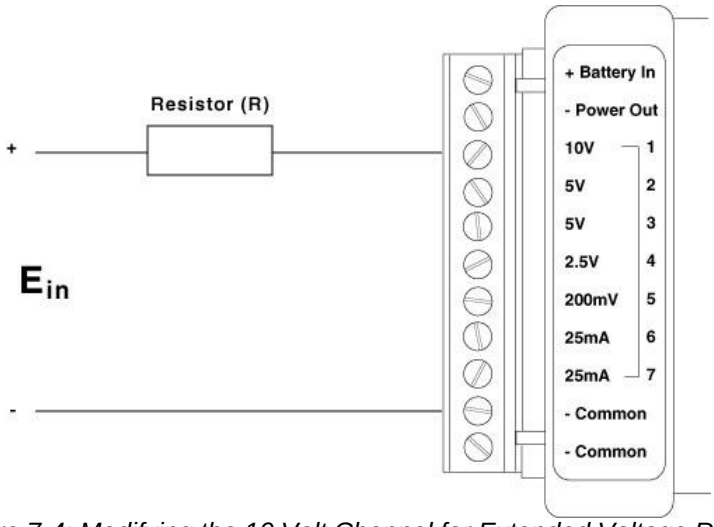

Figure 7-4: Modifying the 10 Volt Channel for Extended Voltage Range

You can also easily convert the 10V channel to measure 0 to 100mA current simply by putting a 100 ohm resistor (minimum rating: 2 watts) between the "**10V**" and "**-Common**" terminals.

5 Volt Channels

The two 5 volt channels can be modified to span higher ranges (greater than 5V DC) by adding a single resistor, in the same way as shown for the 10V channel in Figure 7-4, to either, or both, of the two "**5V**" terminals. The value of the resistor (R) can be calculated by the following equation based on the desired voltage input range (Ein):

R = 4,000 * Ein - 20,000

For example, if you wish to measure up to 20 volts, the resistor value should be:

4,000 * 20 - 20,000 = 60,000 ohms

Since you will not always be able to get the exact resistor value that you calculated, you can determine the actual input range you will have by plugging the value of the resistor back into the formula:

Ein = R + 20,000 / 4,000

You can easily convert either or both 5V channels to measure 0 to 50 mA current by wiring a 100 ohm resistor (minimum rating: 0.5 watts) between the "**5V**" and "**-Common**" terminals.

2.5 Volt Channel

The 2.5 volt channel can be modified to span higher ranges (greater than 2.5V DC) by adding two resistors to the input terminals as shown in Figure 7-5. The value of the resistor marked "**10k**" must be 10,000 ohms ±1% or better. The value of the resistor (R) can be calculated by the following equation, based on the desired voltage input range (Ein):

R = 4,000 * Ein - 10,000

For example, if you wish to measure up to 20 Volts, the resistor value should be:

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4,000 * 20 - 10,000 = 70,000 ohms

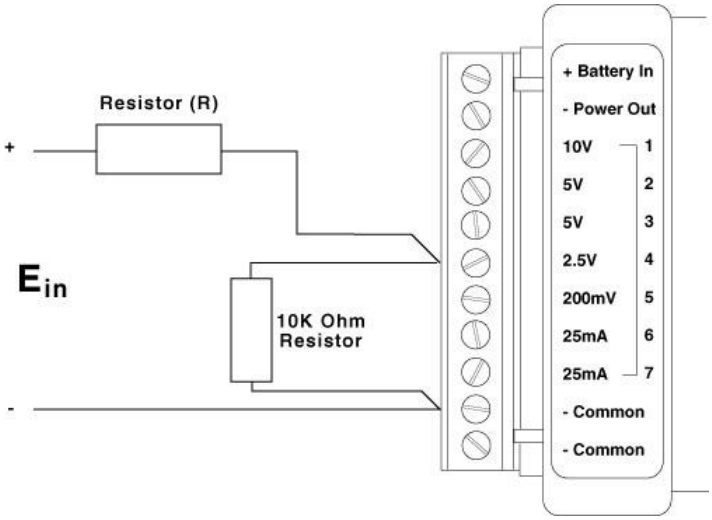

Figure 7-5: Modifying the 2.5 volt channel

Since you will not always be able to get the exact resistor value that you calculated, you can determine the actual input range you will have by plugging the value of the resistor back into the formula:

Ein = R + 10,000 / 4,000

This value will be needed when it comes time to create your own custom equation using TrendReader software.

You can easily convert the 2.5V channel to measure 0 to 25 mA current by wiring a 100 ohm resistor between the "**2.5V**" and "**-Common**" terminals.

200 millivolt Channel

The 200 millivolt channel can be modified to span higher ranges (greater than 200 mV DC) by also adding two resistors, in the same way as shown for the 2.5V channel in Figure 7-5. The value of the resistor marked "**10k**" must be 10,000 ohms ±1% or better. The value of the resistor (R) can be calculated by the following formula, based on the desired voltage input range (Ein):

R = 50,000 * Ein - 10,000

You can also modify the 200 mV channel to log current loop signals with greater sensitivity than the two 25 mA channels. Put a 100 ohm resistor across the "**200mV**" and "**-Common**" terminals and you will be able to log currents from 0 to 2.0 mA with approximately ten times the resolution of the 25mA channels. The equation to use to determine other current (Iin) ranges, in milliamps, is:

R = 200 / Iin

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25 milliamp Channel

The 25 milliamp channel can be modified to span higher ranges (greater than 25mA DC) by also adding a single resistor across the input terminals as shown in Figure 7-6. The value of the resistor (R) can be calculated by the following formula, based on the desired current input range (Iin) in mA:

$$R = 2{,}500 / (Iin - 25)$$

Make sure the resistor can withstand at least twice the power you will be sending it. To calculate this, use the following equation:

$$P = 2 \times I_n^2 \times R$$

Where:

P = Minimum Power Rating of resistor (in watts)
Iini= Maximum amperage expected through resistor (in Amps)
R = Resistor value (in ohms)

For example, a 50 ohm resistor calculated to measure currents up to 75mA will require a power rating greater or equal to 0.56 watts. Therefore, a one watt resistor will be fine.

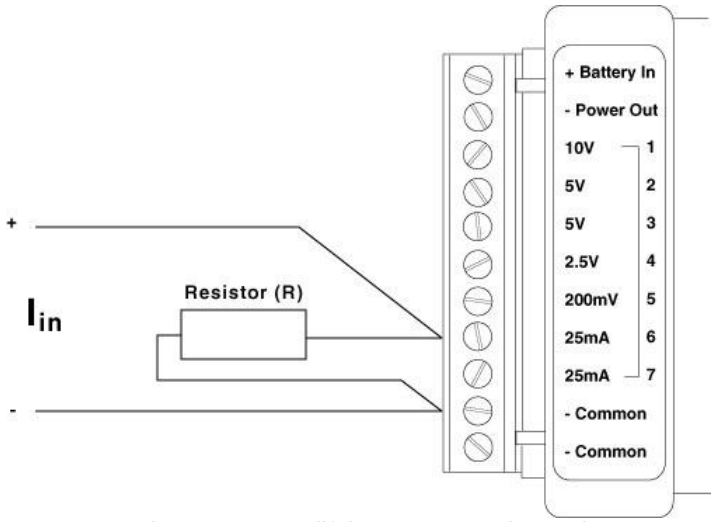

Figure 7-6: Modifying a 25mA Channel

For increased sensitivity at lower current ranges down to 2.5 milliamps, refer to the section for modifying the 200 mV channel.

Resistors

Resistors that can be used with the SmartReader 7 are readily available at most electronic parts supply stores. Ask for precision 1% metal film resistors with a temperature coefficient of less than 500ppm. The most common ones are quite small and made in the form of a cylinder with axial leads. To show the value of the resistor, either there is:

- a color code painted on each resistor in the form of bands
- a number (followed by a letter) stamped on them

For resistors with a tolerance of 2% or looser, there are four bands or three number digits

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while the resistors that are 1% or better have five rings or four number digits. In the case of 1% values the first three digits or rings correspond to the resistors value and the fourth digit or band is the number of zeros to be added. The fifth band or letter indicates the manufacturer's tolerance of the resistor. For example, a 30,900 ohms resistor would be shown as orange, black, white, red, black or "3092F".

Color	Number	Tolerance	Letter
Black	0	1%	F
Brown	1	2%	G
Red	2		
Orange	3		
Yellow	4		
Green	5		
Blue	6		
Violet	7		
Grey	8		
White	9		
Gold		5%	J
Silver		10%	K
None		20%	

WARNING: Using resistors with tolerances looser than 1%, poor temperature coefficients and long-term drift characteristics will create undesirable measurement errors.

1.9.5 External Battery Control

You can activate a special switch on the SmartReader 7 designed to optimize the use of battery-powered sensors while out in the field. The battery-saving contacts can provide switching capability to draw power from the battery only when needed, thus maximizing its life for extended field applications.

The battery switch allows you to power external transducers with a separate battery pack. This capability makes it easy for you to assemble your own self-contained data logging kit for long-term in-field use where there is no convenient power supply receptacle.

The battery switch is enabled in TrendReader software. The switch works by closing eight seconds prior to a reading, remaining closed until the reading is taken, then immediately

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opening again before repeating the cycle (Figure 7-7).

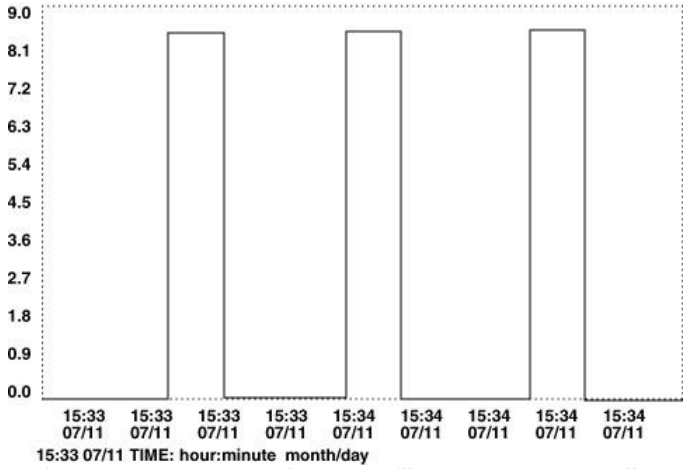

Figure 7-7: Battery Voltage Profile at 32 sec. Sampling

It extends battery life by only drawing power, when necessary, to meet the input requirements of the transducer or transmitter circuit that you want to monitor (Figure 7-8).

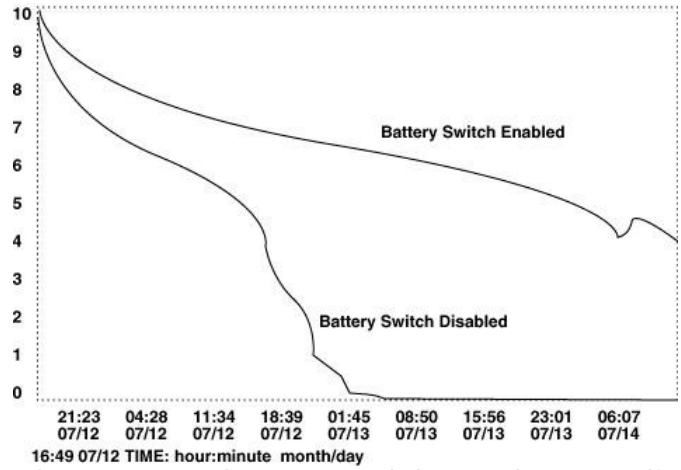

Figure 7-8: How the Battery Switch Extends Battery Life

To use the battery switch, the battery's positive (**+**) terminal must be wired to the "**+ Battery In**" terminal on the SmartReader 7 (refer to Figure 7-9). The power to your external transducers will then be available from the "**+ Power Out**" terminal. The battery's negative (**-**) terminal can

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then be wired to either of the "**- Common**" terminals.

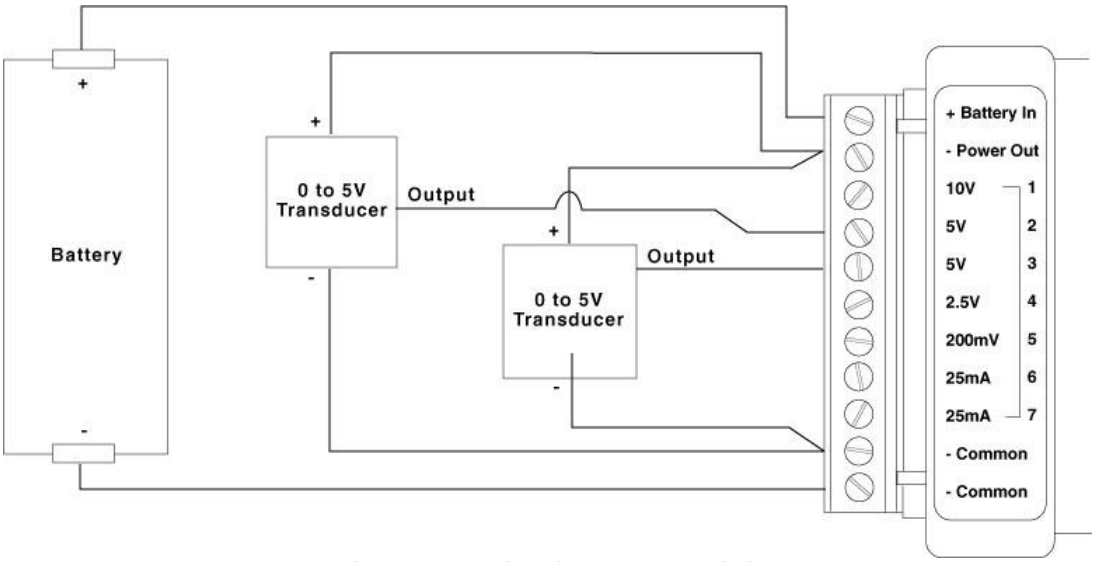

Figure 7-9: Using the Battery Switch

The maximum current that the battery switch can source is 100mA. Battery supply voltage can be from 9 to 25 volts. Short circuit protection is continuous at 9 volts, but only one second at higher voltages.

Things you should know about batteries

When using batteries for powering your external sensors and transducers, you should keep in mind these key points:

1. The rated voltage of a battery only applies to initial use. Once under load, the voltage will decrease gradually until completely drained (refer to Figure 7-8). By knowing how the battery voltage is affected through use you can make sure that the voltage requirements of your external transducers will be met. A good rule of thumb to follow is to exceed the minimum required input voltage for your transducers by at least two times (where acceptable).
2. Nickel-Cadmium (rechargeable) batteries self-discharge at a rate approximating 1% of their remaining capacity per day. This should be taken into account for extended logging sessions.

Determining how long your batteries will last

To estimate how long your batteries will successfully power your external sensors and transducers, you will need to know both the capacity of the batteries as well as the proposed resistance presented to them by the load (your own transducers).

Battery capacity, usually expressed in milliampere-hours (mAh), is the total amount of electrical charge a cell can store or deliver. Unfortunately, most commercially-available batteries are sold without any of this capacity information listed. To get this information you can usually call one of their local representatives.

As a general guide, most good quality nine volt batteries have a capacity of approximately 500 mAh. This means, at an average continuous current draw of 50mA, it will deliver approximately ten hours of service.

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The load you impose on your battery will depend on how many transducers you intend to have in your logging circuit. The greater the number of transducers, the greater the power draw from the battery. If you are logging from a 4 to 20mA transducer, the maximum current it will draw will be approximately 20mA. If you power it continuously, your 500 mAh battery should not run out until you have had at least twenty-five hours of service. Since your transducer probably will not always draw maximum current (12mA might be a more reasonable figure), you can probably expect up to forty-two hours of service.

The battery-saving switch contacts can increase the lifetime of your external batteries significantly. Since the batteries will be powered only for eight seconds out of every logging interval, the power draw on the battery will be reduced considerably.

Example

Problem: *You want to log pressure once every thirty minutes from a 0 to 300 psig transducer. The output of the transducer is 4 to 20mA. The excitation voltage is listed at between 9 and 40 volts DC.*

Solution: From this information we know that a 4 mA signal will represent 0 psig and a 20 mA signal will represent 300 psig. Since the minimum excitation voltage is 9 volts, we should supply at least 18 volts initially from our batteries. We can do this by simply connecting two nine volt 500 mAh batteries in series.

Without the battery-saving switch enabled, our minimum expected battery life would be approximately twenty-five hours. With the switch enabled, and thus closing only eight out of every 1,800 seconds (or thirty minutes), the life will be extended by a factor of 225 (or 1800/8). This means that we should be able to log from this transducer for over 5,625 hours, or over 234 days. Actual life may even be higher depending on what pressures are actually recorded (the lower the pressure, the lower the power draw).

Regulated Voltages

The unstable voltage characteristics of batteries makes them, by themselves, incompatible for use with transducers that require a regulated voltage supply. You can, however, add your own voltage regulator to your transducer circuit to compensate for this instability (see Figure 7-10). Voltage regulators are readily available at most electronic parts supply stores.

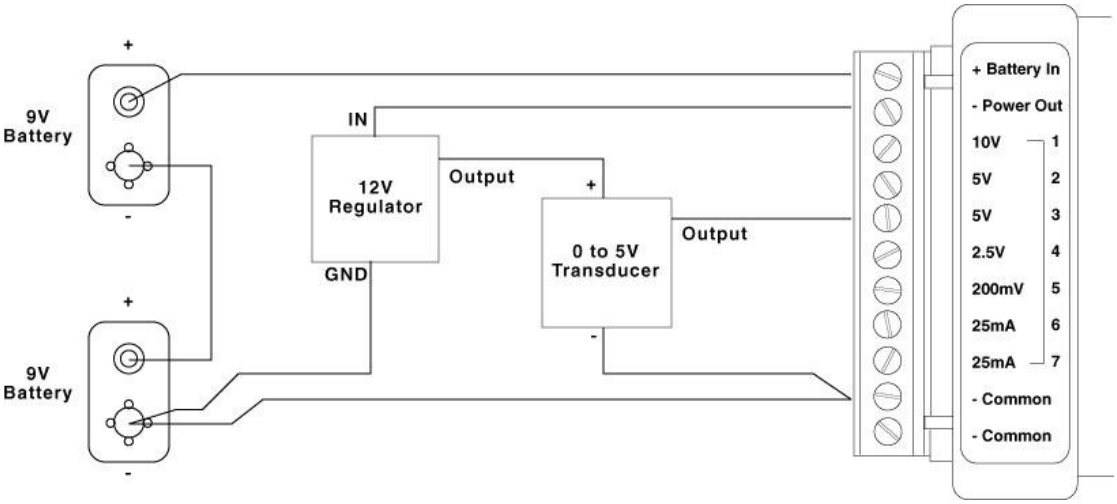

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Figure 7-10: Regulating Battery Supply Voltage

Make sure that your supply voltage to your regulator is at least two volts higher than the level to which you want to regulate to. To do this, you can easily increase the voltage of your batteries by hooking them up in series as shown in Figure 7-10.

If the wires between the voltage regulator, batteries, and transducers are long (more than a few inches), the regulator may oscillate and produce an unstable voltage. You can correct for this by connecting one 0.1 microfarad capacitor to each of the regulator's outside pins then wiring them to the regulator's center pin. Make sure to keep the capacitor leads as short as possible.

1.9.6 Selecting Transducers and Transmitters

A *transducer* is defined as a device that receives energy from one system and retransmits it, in a different form, to another system. A *transmitter* is a term usually reserved for transducers in a current loop circuit. In this section, the terms transducer and transmitter will be used interchangeably.

For a transducer to be useful, the retransmitted signal must be compatible with standard instrumentation. For the SmartReader 7 Logger, this can be either in the form of an analog DC voltage or current.

Many compatible transducers exist for measuring such variables as temperature, relative humidity, pressure, speed, PH, and more. You can obtain these from a wide variety of manufacturers or distributors. An extensive listing of sensors and companies is published yearly by *Sensors* Magazine.

To figure out what to look for when choosing transducers, it is helpful to know a few technical terms and how they relate to use with your SmartReader 7 logger.

Excitation Voltage
This term refers to the input voltage that a transducer requires in order for it to work properly. It is either specified as a range (for example, 9 to 30 volts DC) or as a specific voltage (for example, 10 volts DC). When a range is specified, it means you can use an unregulated power supply (such as a battery) as long as voltages within the range are provided. Usually, if a specific voltage is required, it means you require a regulated power supply.

When an unregulated power supply is specified for the excitation voltage, a regulated one may also be used. The reverse, however, is not true. Millivolt pressure transducers, for example, usually require regulated power supplies.

Maximum Impedance
An important consideration when choosing transducers is the requirement for input or loop impedance. This simply refers to how much resistance your instrumentation (for example, the SmartReader 7) can have before it will begin to cause problems. For voltage inputs, a very high impedance is usually required (usually greater than 10k ohms). This prevents the unnecessary draining of current from the transducer circuit. The SmartReader 7's voltage inputs are all high impedance (greater than 20k ohms).

For current loop inputs, it is advantageous to have a very low impedance (the SmartReader 7's

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current channels have a low 100 ohm impedance). This helps to minimize the voltage requirements and power consumption of the circuit. Check the specifications for the transducers you intend to use to ensure the SmartReader 7's input impedances are acceptable.

Two-Wire Transmitters
Two-wire transmitters are transducers that form part of a current loop circuit. They vary the current flow in accordance with changes in the variable which they are sensing. Most two-wire transmitters have a 4-20mA output.

Three-Wire Transducers
Three-wire transducers have three connections: a supply (excitation) voltage input (V+IN), an output voltage (V+OUT) and a common (COM-). You can usually tell if a transducer is 3-wire by reviewing the wiring diagram and looking for a *single* common connection.

Four-Wire Transducers
Four-wire transducers fall into two categories: line-type and Wheatstone bridge types. No more than one line-type transducer can be attached to a SmartReader 7 unless it has an isolated output (no electrical connection to the line). Bridge-type transducers can only be hooked to a SmartReader 7 if they are signal conditioned.

Output
The specified output of a transducer or transmitter will determine whether it is compatible for use with your SmartReader 7. Some of the most popular transducer outputs (such as 0 to 2.5V or 0 to 5V DC) are directly compatible with the logger. The most popular transmitter output is 4 to 20 mA which can be easily used with the SmartReader 7.

1.9.7 Specifications

Voltage and Current Inputs

Standard Ranges:	0 to 2.5 volts DC (1 channel) 0 to 5 volts DC (2 channels) 0 to 10 volts DC (1 channel) 0 to 200mV DC (1 channel) 0 to 25mA (2 channels)
Accuracy:	±1% F.S.
Input Impedance:	>1 M ohms (0 to 200 mV channel) >1 M ohms (0 to 2.5 V channel) 20 k ohms (0 to 5.0 V channels) 40.9 k ohms (0 to 10.0 V channel) 100 ohms (0 to 25 mA channels)
Maximum Input Voltage:	Voltage channels: ±40 V (reverse polarity protected) Current channels: ±70 mA (reverse polarity protected)

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Connections: Removable screw-type terminal strip

Specifications are subject to change without notice.

1.9.8 Applications

The SmartReader 7 Logger can be used for a wide variety of data recording applications. You may decide to use it as a direct replacement for your existing analog voltage or current loop strip chart recorders. That way you will be able to easily get valuable data into your computer, instead of always being restricted to just the charts.

You may also want to set up your own self-contained logging stations for monitoring commercially available transducers and transmitters (for example: temperature, pressure, humidity, wind speed, flow, level, pH, position, and more). That way you will be able to easily set up your SmartReader 7 in the field with a minimum of trouble.

Application Example
Here is an example to guide you in your own SmartReader 7 applications:

Problem: *You want to monitor static pressure in a duct, over a period of about a week, to determine how a fan is performing in an air conditioning system. The location you want to monitor is not very accessible and there is no nearby power supply. It is estimated that the pressure in the system will vary as much as 3 to 4" W.C. (.75-1.00 kPa)*.

Solution: You decide a self-contained logging station is the best solution. For the pressure measurements you choose a Model 264 0 to 5" (0 to 1.25 kPa) unidirectional transducer from Setra Systems. The 264 requires an unregulated excitation of 12 to 28 volts DC to produce a linear 0 to 5 volt DC output signal.

Figure 7-11 illustrates the setup of this logging station using two 9 volt batteries wired in series

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(to produce an initial eighteen volt supply).

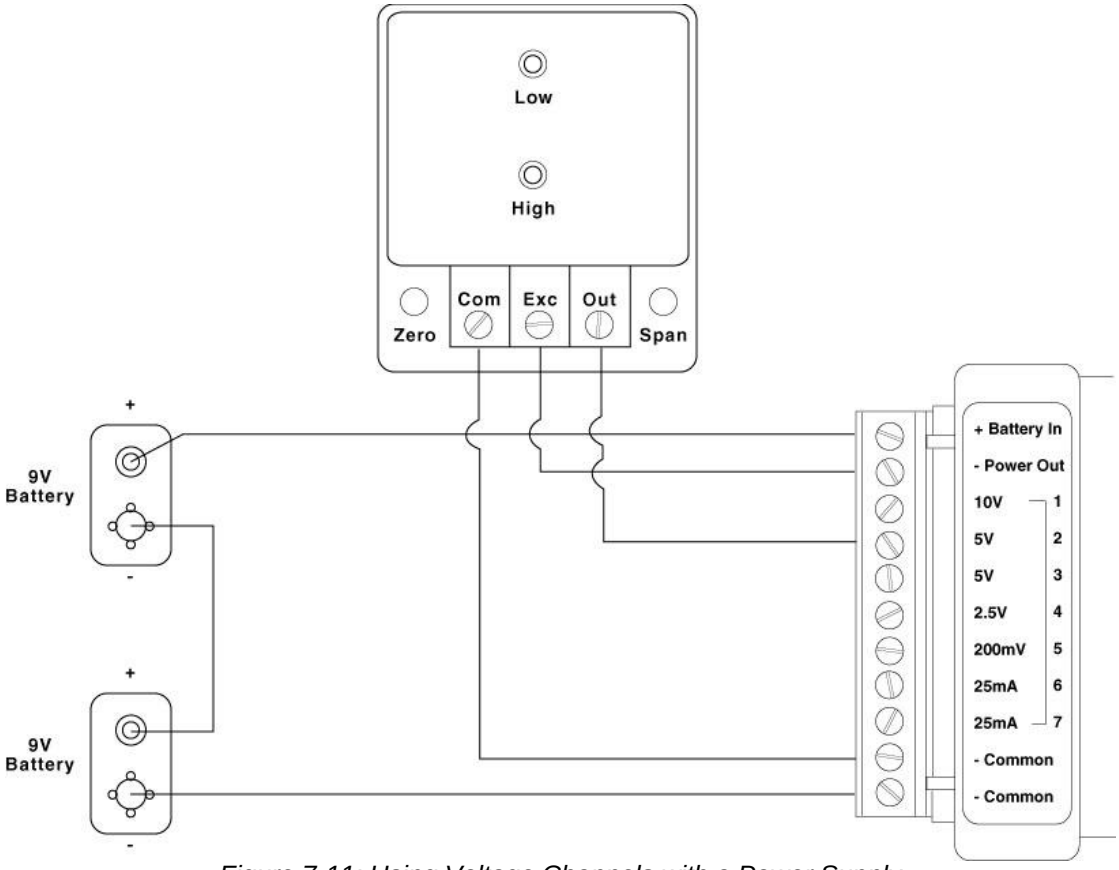

Figure 7-11: Using Voltage Channels with a Power Supply

To set up the SmartReader 7 you first disable all the input channels except for one of the 5V channels. You set this channel with a sampling rate of 2 minutes and activate the battery switch. That way you will minimize battery consumption and maximize memory, allowing you to collect over forty-five days of data. It will also leave plenty of time for you to retrieve the logger after the logging session and transfer the data to your computer.

Before heading out into the field, write a simple equation converting the 0 to 5 volt signals into the 0 to 5" W.C. pressures. See your TrendReader software guide for information on writing custom equations. After saving the equation to the 5V channel, you can then test the logger's operation by viewing channel's Realtime reading using TrendReader software.

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1.10 SmartReader 8 Eight-Channel Temperature Logger

The SmartReader 8 is a versatile logger for recording temperatures in a wide range of environmental and industrial applications. It can record up to eight temperature channels simultaneously.

Figure 8-1: SmartReader 8

1.10.1 Description

The SmartReader 8 has seven external temperature channels (for remote temperature probes) and one internal thermistor sensor.

1.10.2 Setup and Use

The following procedure will help you prepare your SmartReader 8 for your temperature monitoring applications.

1. Setup and activate the channels you intend to monitor using TrendReader software. Disable any channels you are not going to use to conserve memory.

2. If you are using external channels, make sure to use thermistor sensors appropriate for the measurements you want to take (for assistance, please refer to Appendix C Thermistor Temperature Probes). Also, confirm that the equation number you are using for each of your probes is correct.

3. To connect remote temperature probes (two-wire), simply wire one lead into a channel input (labeled **1** to **7**) and the other into a terminal marked **Common**. It does not matter which lead goes to which terminal. You can connect more than one thermistor probe to the same **Common** terminal. For example, Figure 8-2 shows two external probes connected to channels 2 and 3 sharing the same **Common** terminal. If you are using a thermistor probe with shielded cable, terminate the shield wire by connecting it to any **Common** terminal.

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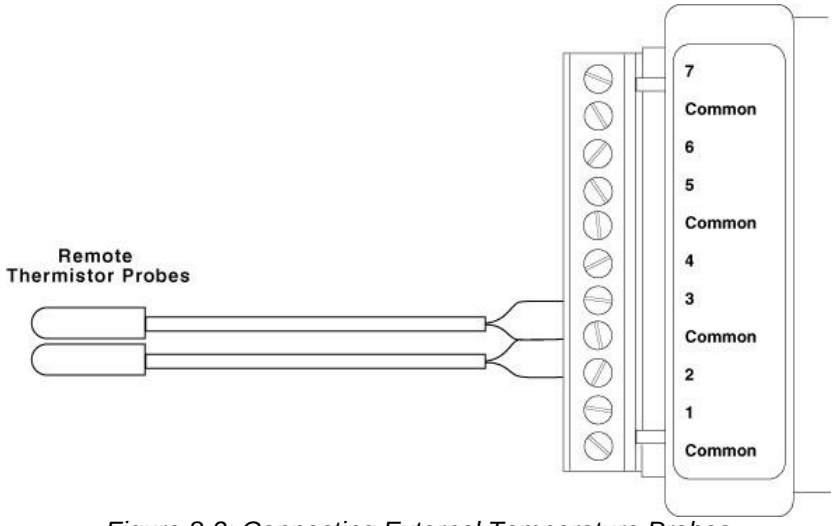

Figure 8-2: Connecting External Temperature Probes

Accessories

The ET Series Temperature sensors are thermistor probes that can be used easily with your SmartReader 8 for remote temperature measurements. The advantage of these probes is that they can be used for a wider range of temperatures, are very versatile (they can be used to liquid or surface temperatures), and their small size permits them to be easily inserted in hard-to-get-at locations such as in ductwork or under pipe insulation.

For more information on choosing and using thermistor probes, refer to Appendix C Thermistor Temperature Probes.

You can purchase additional screw-type terminal block connectors for your SmartReader 8. These make it easy to permanently install sensors around buildings and systems. Simply wire them to the unconnected blocks and when you are ready to collect data, you can simply plug in your SmartReader 8 logger. For analysis, you can just unplug it again without having to disconnect any sensors.

Other Applications

For information on how you can monitor resistance or switch status with your SmartReader 8, refer to Appendix A Monitoring Resistance and Switch Status.

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1.11 SmartReader 9 Pulse Logger

The SmartReader 9 is a three-channel, multi-purpose counter and logger. With it you can monitor a wide variety of measurement parameters.

Figure 9-1: SmartReader 9

1.11.1 Description

Featuring two input channels configured for easy interface with common switch and transducer outputs, SmartReader 9 has the capability to count, totalize, and record voltage pulses and switch contact closure frequency as well as monitor ambient temperature from -40 to 70°C (-40 to 158°F).

1.11.2 How the SmartReader 9 Counts

The SmartReader 9 can count and log data from either of its two external input channels. The channels can count the opening and closing of external switch contacts and/or the occurrence of DC voltage pulses.

The SmartReader 9 keeps track of the number of times a switch opens and closes by continuously maintaining a voltage potential across the input terminals. Figure 9-3 shows a simple circuit for monitoring such a switch. Every time the voltage potential changes from high to low (i.e. switch opening) and back to high again (i.e. switch closing) the logger registers a count of '1.'

Using the standard 32/sec. counting channel in the Normal Rate mode, the logger can count up to 256 switch contact closures over any eight second period (or an average of 32 closures per second). At the end of every eight second period the total number of counts is stored in a memory buffer. If the logger's sampling rate is set for eight seconds this total is immediately saved to memory as a reading. If the sampling rate is more infrequent than eight seconds the total number of counts for each eight-second period is added up and then averaged for the amount of the sampling rate.

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Counting voltage pulses (also called logic inputs) is similar to counting switch contacts, only instead of the logger supplying the voltage potential, the logger detects the voltage level of the pulse. The pulse must have a low level voltage less than 0.5 volts DC and the high level voltage must be from 4.5 to 24 volts DC.

The minimum pulse length and minimum interval between pulses must be 4 milliseconds. For the SmartReader 9 to register a count of '1,' the input voltage must go from a low level to a high level and back again to a low level.

You can configure each of the two counting channels for any one of three possible rates: 32, 64, and 128 Hz (pulses per second). When the rate select jumper is attached to the 32/sec. setting, the logger can count up to 256 pulses every eight seconds. If the number of counts exceeds 256, the counting will restart from zero thereby producing an incorrect reading.

1.11.3 Quick-Start Tutorial

By setting up the following simple application, you can gain a basic understanding of how this logger works. The concepts learned here will help you use your SmartReader 9 correctly for your own applications.

This section assumes you are familiar with the basic operation of TrendReader software. If you need help, please refer to the TrendReader guide.

1. Start TrendReader software and connect the SmartReader 9 to your PC via the interface cable.

2. Select equation 34 for the Pulse 1 channel, ensure that the channel is enabled, and choose Normal counting mode (do not activate the logger's Accumulate mode). Save the setup to the logger.

3. Observe the Realtime reading. It should be 0.0 Hz.

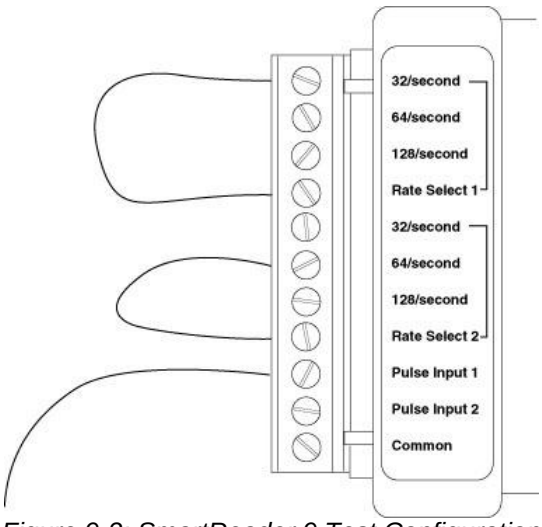

Figure 9-2: SmartReader 9 Test Configuration

4. Connect the three wires to your logger as shown in Figure 9-2 with one wire going from

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"Rate Select 1" to "32/second," one wire from "Rate Select 2" to "64/second" and the third wire from "Pulse Input 1" left unconnected.

5. Now tap (touch and release) the third wire to the screw head of the terminal marked "**Common**." Do this continuously at a rate of about once per second. The Realtime reading from the "Pulse 1" channel should be close to "1.0 Hz" depending on how accurately and steadily you are tapping.

6. Try varying the rate at which you tap to see how the Realtime display changes.

Each time you tap the wire to the "**Common**" terminal you are simulating a switch opening and closing. Note that these readings are in Hertz (Hz) which refers to the number of pulses or switch contact closures the logger detects per second. This is because the logger totalizes the number of contact closures (or pulses) it detects in periods of eight seconds at a time. It then expresses this in Hertz (or pulses per second).

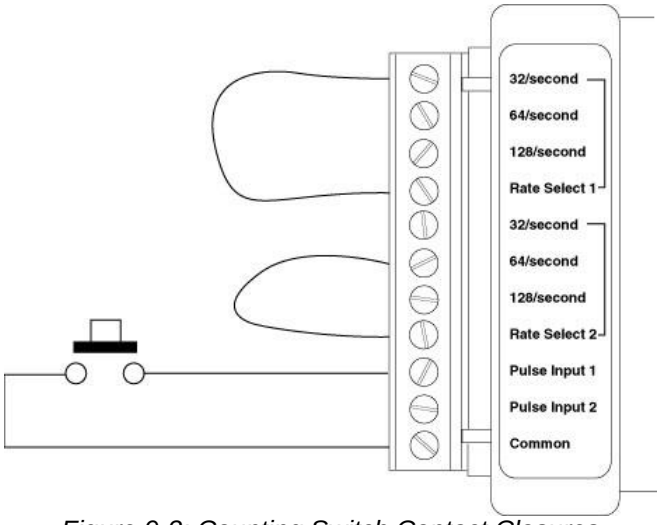

Figure 9-3: Counting Switch Contact Closures

1.11.4 Using Your SmartReader 9

The following steps will guide you through the procedure of setting up and using your SmartReader 9 Pulse Logger.

1. Always make sure that the circuit you want to monitor will be compatible for use with your SmartReader 9. Refer to the Specifications section for details on the type of switches and logic signals that will work. Key things to note are:

   - If you are going to be monitoring the opening and closing of switches, then there must not be a power source connected to the contacts (the contacts must be "dry").

   - If you wish to monitor a circuit that produces pulsed signals, then the low level must fall between 0 and 0.5 volts DC and the high level must be between 4.5 volts and 24 volts DC.

   - The frequency of the pulses or contact closures that you want to monitor must not exceed the maximum capability of the SmartReader 9 which is 1024 over any eight

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second period (using the 128 pulses/sec. channel).

2. Decide which mode you want to have your SmartReader 9 count in. For more information on the two choices you have -- Normal Rate mode and Accumulate mode -- refer to the Counting Modes and Equations section.

3. Connect the Rate Select jumpers to the correct positions for your application, and choose the corresponding equation or write your own custom equation. Custom equations allow you to convert raw readings from a circuit (in Hz) to the units you require (for example, litres per second). See your TrendReader software guide for more information on custom equations).

4. Connect your transducers or transmitters and check the operation of the logger by viewing the Realtime readings in TrendReader software. If you can, try and exercise your transducers (make them change their output) to ensure that everything works properly. If it does, then you are ready to place your assembly in the field to start logging your data.

1.11.5 Rate Select Connections

The maximum number of pulses the logger can count in any eight-second period is 255, or about 32 pulses per second. To count more than this, you need to divide the pulse rate down to less than 32 pulses per second. This can be done by altering the Rate Select jumper connections.

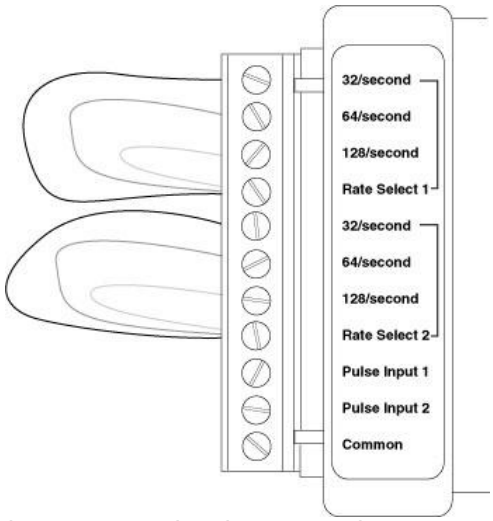

Figure 9-4: Setting the Rate Select Jumpers

For each pulse channel, the rate select terminal should connect to the 32/sec. terminal (to count every pulse), to the 64/sec. terminal (to count every second pulse) or to the 128/sec. terminal (to count every fourth pulse). Do not connect any external device to the 32/sec., 64/sec., 128/sec. or rate select terminals. These connections are only for selecting internal rate. For each channel, make sure that one of the 32, 64, or 128/sec. terminals is connected to its own rate select terminal. If you connect more than one of these at a time for each channel, the logger will not count pulses. If you do not connect any of these, the logger also will not count pulses.

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1.11.6 Counting Modes and Equations

There are two counting modes for the SmartReader 9, Normal Rate and Accumulate mode. These modes are selected using TrendReader software. The mode you select applies to both logger channels. Make sure you choose equations for both channels that match the counting mode.

Normal Rate Mode
The Normal Rate mode counts and records a totalized reading in a buffer, then restarts counting at a fixed rate of once every eight seconds. The logger uses these eight-second totals to determine the actual reading it records in memory. Depending on how you set up your logger's sampling rate, the readings you obtain may be calculated by averaging the eight-second counts that make up the logger's sampling rate. For example, if your logger is set to take a reading every two minutes, then each reading the logger stores will consist of the average of fifteen eight-second intervals. If the logger counts 150 pulses in the first eight-second interval, and there are no pulses during the other fourteen eight-second intervals, your logger will average all fifteen intervals and store a raw byte value of 10. This indicates that during the two-minute interval there were an average of ten pulses per eight-second time period. The Normal Rate mode equations read out directly in Hz (pulses per second) both in Realtime display and during graphing.

Accumulate Mode
The Accumulate mode counts and records a totalized reading to memory at a frequency matching the sampling rate that you have set for your logger. For example, if your logger is set to take a reading every two minutes, then each reading the logger stores will consist of the total of all the pulses that occurred during the two minutes. The Accumulate mode equations read out in pulses per logger time interval during graphing. In Realtime mode, TrendReader software displays pulses per eight-second period.

Equations
There are six possible methods of operation for each of the SmartReader 9's two pulse channels. That is because there are three rate select jumper settings and two counting modes, Normal Rate mode and Accumulate mode. To collect correct data, you must select the equation that relates to your logger settings. The Rate Select Table provides you with a summary of these equations.

For each equation number listed in the following table, the corresponding information is provided:

- The counting mode the logger has been set to operate in ("A" for Accumulate mode, "N" for Normal Rate mode).
- The required setting for the rate select jumper on your logger. The maximum number of pulses that this configuration can count up to during an eight-second period (for normal rate mode) or the logger's sampling rate (for accumulate mode).
- The contents of the equation itself which you can use to create custom equations in your own choice of engineering units (i.e. flow rate in gpm, traffic in cars/minute, or speed in km/hour).

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Rate Select Table

Equation Number	Counting Mode	Rate Select Setting (Pulse/Sec.)	Maximum Pulses	Equation Coding
31	A	32	256	answer0 = source0
32	A	64	512	answer0 = source0 * 2
33	A	128	1024	answer0 = source0 * 4
34	N	32	256	answer0 = source0 / 8
35	N	64	512	answer0 = source0 / 4
36	N	128	1024	answer0 = source0 / 2

1.11.7 Specifications

Pulse Inputs (General)

Standard Ranges: 32, 64, and 128 pulses/second.

Resolution: 8 bits

Accuracy: 32 Hz Channel: ±1 pulse/8 seconds
64 Hz Channel: ±2 pulses/8 seconds
128 Hz Channel: ±4 pulses/8 seconds

Maximum Voltage: ±40 volts (reverse polarity protected)

Connections: Removable screw-type terminal strip with single common (-) connection

Totalizing: Eight seconds. Average pulse frequency over this period must not exceed the channel range or counting will restart from zero.

Minimum Pulse width: 4 milliseconds

Input Types:

Contact: Uncommitted ("dry") switch or relay contacts (internally generated pulses). Switches with gold-plated sealed contacts are recommended.

Excitation: 5 microamps contact current, 3.5 volts open circuit

Logic: Active logic signals

Input Voltage: Low = 0 to 0.5 volts (DC)
High = 4.5 to 24 volts (DC)

Input Impedance: 750k ohms

Specifications are subject to change without notice.

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1.12 Indoor Air Quality (IAQ) Logger

The Indoor Air Quality (IAQ) Logger, when combined with the Telaire 7001Handheld CO_2 Monitor, records the three leading indicators of indoor air quality, which are temperature, relative humidity, and carbon dioxide.

The IAQ Logger is a SmartReader data logger.

Figure 10-1: IAQ Logger

1.12.1 Description

The IAQ Logger has five channels; one internal temperature sensor, one internal RH sensor, one CO_2 sensor with an input range from 0 to 2.5VDC, and the remaining two for an optional remote temperature and RH probe (EH-020A).

How It Works
The relative humidity sensor in the IAQ Logger is a processed plastic wafer. This wafer is actually a laser-trimmed, capacitive thin-film relative humidity sensor.

Changes in relative humidity cause the surface capacitance of the polymer film to vary. The IAQ Logger gauges this capacitance by passing a small electric current through it and measuring the relative voltage drop. Because the response of the sensor is temperature dependent, a temperature reading is always taken at the same time as the humidity reading. That way, when the logger's information is backed up into your computer, TrendReader software can automatically factor in the right compensation values when it calculates the percentage of Relative Humidity (in % RH). The result is an accurate set of automatically-generated and temperature-compensated relative humidity readings.

1.12.2 Setup

Make sure to enable each channel you want to use. If you are not using a channel, disable it to save logger memory.

Channel	Description	Equation
0	Internal Temperature	45
1	Internal Relative Humidity	71

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2	External Temperature	Appendix C
3	External Relative Humidity	71
4	0 - 2500 PPM	124

NOTE: When you activate either RH channel, you must also enable its corresponding temperature channel, as well, in order to temperature compensate the RH sensors.

Precautions
The IAQ Logger's RH Sensor is designed for long-term trouble-free performance, but there are a few precautions to keep in mind to maximize the benefit it can give you.

- Never expose the sensor to organic solvents or ionic-laden liquids. Any chemical compound that attracts polymers may affect the sensor.
- The RH sensor is particularly susceptible to contamination by sulfur gases and sulfur compounds. **DO NOT SMOKE NEAR THE LOGGER!**
- Always return your IAQ Logger to a re-sealable plastic bag during non-use to maximize the in-calibration life of the RH sensor.

1.12.3 Accessories

You can obtain replacement RH Sensors, remote temperature probes, temperature and relative humidity probes for use with your IAQ Logger. The IAQ Logger can also be combined with Telaire 7001 to measure carbon dioxide and temperature levels.

ET Series Temperature Sensors
The ET Series Temperature sensors are thermistor probes that can be used easily with your IAQ Logger for remote temperature measurements. The advantage of these probes is that they can be used for a wider range of temperatures, are more versatile (they can be used to record fluid temperatures) and their small size permits them to be easily inserted in hard-to-get-at-locations (such as in ductwork or under pipe insulation).

To use an ET Temperature probe with your IAQ Logger you must first enable the logger's external temperature channel. Connect the remote temperature probe by connecting one wire (of the two-wire probe) to the channel marked **Temperature** and the other wire to the terminal marked **Common.** For more information on ET series thermistor probes, refer to Appendix C Thermistor Temperature Probes.

EH-020A Temperature and Relative Humidity Probe
The EH-020A is a four-wire probe with a temperature and relative humidity sensor. For field-mounting convenience, it also has a magnetic backing and a security eyelet. To use the EH-020A with your IAQ Logger, you must enable the logger's external temperature and humidity channels. To connect the EH-020A probe to your IAQ Logger, follow instruction

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notes packed with each RH probe set -- see Figure 2-2.

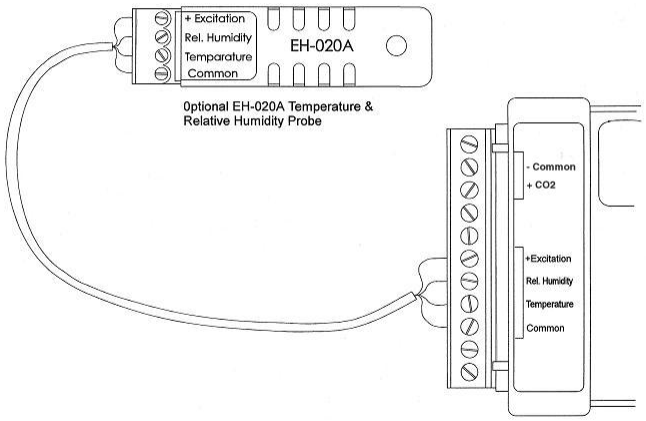

Figure 10-2: Connecting the EH-020A Temperature and RH Probe

The EH-020A is applicable for measurements between -20 and 40°C (-4 and 104°F) and 10 to 90% RH.

> **NOTE:** The EH-020A probe is compatible with loggers that have serial numbers above 20,000 only.

The accurate measurement of temperature and humidity depends primarily on the information supplied by a particular sensor. IAQ Loggers use temperature and humidity sensors with rugged qualities designed for minimal or no maintenance (under normal operating conditions).

The IAQ Logger's on-board thermistor is chemically stable and not significantly affected by aging. It will typically drift less than 0.1°C over a period of several years. The relative humidity sensor, although subject to accuracy degradation when exposed to contaminants and/or extreme environmental conditions, will drift typically less than 1% per year (under clean conditions). You should check your RH sensor periodically and, if necessary, recalibrate or replace it.

1.12.4 Troubleshooting

If you are getting what appear to be wrong readings, consider the following before recalibrating the sensors. Sensors sample the atmosphere (or medium) only in the immediate vicinity of the sensors themselves. The physical state of the atmosphere and its degree of uniformity and turbulence will limit the validity of a measurement at some distance from the sensor. This becomes especially apparent for the measurement of ambient temperature and relative humidity.

In a room, temperature and RH levels may vary dramatically from location to location. Such factors as air stratification, drafts, and proximity to heat or humidity sources (people, equipment, moisture, solar gain, etc.) can contribute to a wide variance in conditions even

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within a small, confined area. The individual sensors associated with your IAQ Logger measure and record temperature and RH only in one location. They do not, in any way, represent an overall reading.

If you decide to check the calibration of your IAQ Logger RH Module using a Sling Psychrometer, keep in mind the following:

- Any instrument that requires a person to be present at, or in very close proximity to the RH sensor in order to get a reading, will have a measurement error introduced to it. That is because the body readily gives off heat and moisture that is especially noticeable at lower RH levels.

- The time taken between slinging the psychrometer and reading it can exhibit several degrees of inaccuracy in the wet bulb reading. Air currents around the body, whether it is slung in the shade of a building or in sunlight, not knowing how to tie the wet sock, its condition, and the purity of water used, all contribute to error. In addition, interpolating the data from a psychrometric chart can add another 2 to 4% to the accumulative error.

For accurate CO_2 sensor readings when using the IAQ Logger in conjunction with a Telaire 7001, make sure that the Telaire 7001 is set with the correct altitude/elevation setting for your locale. The factory default for the Telaire's CO_2 sensor is zero, for elevations higher than 500 feet, an adjustment should be made to ensure optimum sensor readings.

1.12.5 Relative Humidity Calibration

Each relative humidity sensor has been individually calibrated in an environmental chamber with standards traceable to the National Institute of Standards and Technology (NIST).

The IAQ Logger and the EH-020A probe are supplied with a calibration certificate which provides calibration values. These calibration values must be entered in and stored in the logger during initial setup. If your RH sensor is out of calibration, you can simply replace it with a new one.

> **NOTE:** A straight replacement of the RH sensor will introduce an additional +2% tolerance on the RH accuracy. Calibration of the RH channel with the new RH sensor is recommended.

In the event that you wish to confirm the RH calibration of your sensor, you can perform your own field test. Refer to Appendix B Temperature and Relative Humidity Calibrations for more information on RH testing.

Interchangeable replacement RH sensors for loggers are available through your dealer. For best accuracy, it is recommended these be calibrated together with the logger - consult your ACR representative for price and availability of this service. Replacement EH-020A modules which are pre-calibrated are available through your dealer.

1.12.6 Specifications

Temperature Sensor (in IAQ logger)

Type: NTC Thermistor

Range: -40 to 70°C (-40 to 158°F)

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Accuracy:	+/- 0.2°C over the range of 0 to 70°C (+/- 0.3°F over the range of 32 to 158°F)
Resolution:	0.4°C (0.7°F) at 25°F; better than 1°C (1.8°F) between -25 and 70°C (-13 and 158°F); better than 2.0°C (3.6°F) between -40 and -25°C (-40°F and -13°F)

Relative Humidity Sensor & EH-020A

Type:	Capacitive thin polymer film
Range:	0 to 95% (non-condensing)
Accuracy:	±4% from 10 to 90% RH (-20 to 40°C [-4 to 104°F])
Resolution:	Better than 0.4% RH between 25 and 60% RH at 25°C (77°F)
Response Time:	Adequate ventilation reduces the response time which is approximately 5 minutes in still air.
Environmental Conditions:	The RH sensor is relatively immune to chemical contamination but when exposed to extreme environmental conditions, accuracy degradation could result. For long-term stability and reliable readings, the sensor should not be subjected to liquid immersion or exposed to high concentrations of organic solvents, corrosive agents, sulfur gases and strong acids or bases. Dust settling on the sensor surface will not affect sensor performance except possibly to decrease the speed of response.
Chemical Tolerances:	Limits for different chemical groups **1**. Organic solvents typically 1,000...10,000 ppm **2**. Corrosive agents (strong acids S02, H2SO4, Cl2, HCl, H2S etc.) typically 1...10 ppm **3**. Weak acids typically 100...1,000 ppm **4**. Bases typically 10,000...100,000 ppm

CO2 Sensor (in Telaire)

Range:	0 to 4,000 ppm voltage output 0 to 10,000 ppm display
Sensitivity:	+/- 1 ppm
Accuracy:	+/- 50 ppm or +/- 5% or reading (whichever is greater)
Repeatability:	+/- 20 ppm

Specifications are subject to change without notice.

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1.13 APPENDIX A Measuring Resistance and Switch Status

Monitoring Resistance and Switch Status

1.13.1 Measuring Resistance

You can also use your SmartReader 1, 2, 4 or 8 model loggers to monitor resistance, instead of just temperature. This capability allows you to monitor devices other than just thermistors (for example, potentiometers, level indicators, or any other device that varies resistance in accordance with a known parameter).

To use the thermistor temperature channel on your SmartReader data logger to measure resistance, you must change the channel's equation number to the one for resistance. To do this, choose **Equation 44 - Resistance** when setting up the logger in TrendReader software.

The highest resolution of the resistance measurements occurs at a 10k ohms midpoint.

1.13.2 Monitoring the Status of Switches

You can also use your SmartReader 1, 2, 4 or 8 model loggers to record the status of uncommitted mechanical switch contacts (see Figure A-1). The switch you want to monitor must be a "dry" contact, which means that it must have no connection to any type of voltage, power or ground.

To use the thermistor temperature channel on your SmartReader data logger to monitor switch status, you must change the channel's equation number to the one for switch status. To do this, choose **Equation 41 - Switch Status** when setting up the logger using TrendReader

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software.

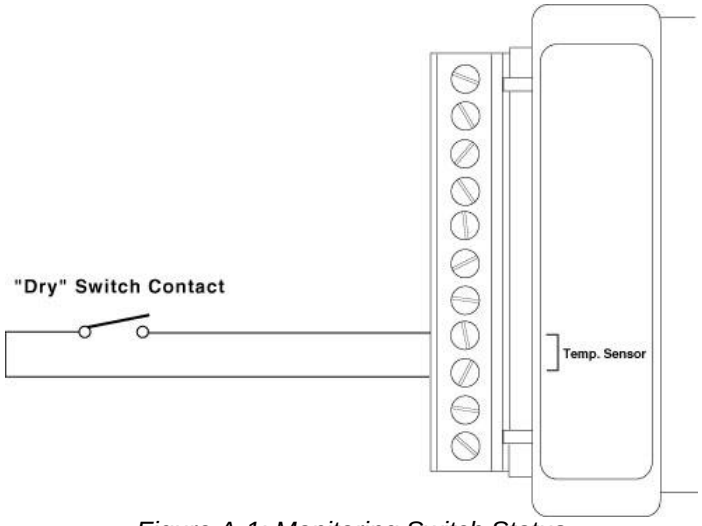

Figure A-1: Monitoring Switch Status

When monitoring the status of a switch with your data logger, keep in mind that the logger will not detect more than one change per sample period. For this reason, use a fast sample rate if you expect the switch to open and close frequently.

The type of graph produced when monitoring switch status is a square wave that rises to a maximum value when the switch is closed, and falls to a minimum value when the switch is open.

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1.14 APPENDIX B Temperature and Relative Humidity Calibration

Temperature and Relative Humidity Calibration

1.14.1 Temperature and Relative Humidity Calibration

This chapter provides instructions on how you can recalibrate your RH modules, EH-020A External Temperature and Relative Humidity probes and any thermistor temperature probes.

1.14.2 Thermistor Calibration

If you do not have accurate resistance-temperature data on your thermistors (available with all interchangeable types) and want to calibrate your own, or simply want to confirm sensor accuracy, you can perform a simple calibration procedure that will give you the right information.

Items You Will Need
Here is a list of items you will need:

- an accurate thermometer, preferably one with 0.1°C increments or better
- a bucket
- crushed or chipped ice
- a pot of boiling water
- a digital multimeter, preferably one with 0.1% resolution, or better

Test Procedure
Make sure the thermistors and leads you want to test are properly potted (waterproofed), insulated or otherwise protected against moisture. You should not dip an unprotected thermistor in water since the water will short the leads and produce false readings. For this procedure use Equation 44.

1. Label each thermistor sensor so that later you may easily match it to the calibration equations you produce.

2. Fill the bucket with the crushed or chipped ice. Add water so that it overflows. Add more ice until it is tightly packed right to the bottom of the bucket (allowing water to overflow).

3. Insert the thermometer and the thermistor probes into the bucket ensuring that they do not touch the side or bottom of the bucket. Make sure the thermistor probes' leads are long enough for you to easily take resistance readings.

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4. Cover the bucket with foam chips or another suitable insulating material. Let sit for at least five minutes while the temperature stabilizes and the thermistor has a chance to respond. If the test is to continue for more than a few minutes, add more ice periodically, as before, insuring that it is tightly packed to the bottom of the bucket each time. The goal is to ensure that the thermistors are always in contact with an ice / water mixture over their entire surface.

5. Measure the temperature of the water (it should be very close to 0°C) and the resistance of the thermistor. This is the Low calibration point data.

6. Next, fill up a pot of water and heat it up till it reaches approximately 50°C. Once the temperature and thermistor have stabilized, again take an accurate reading of both the temperature and the thermistor's resistance, and record. This is the Mid calibration point data,

7. Now heat the water so it boils. Record the temperature (100°C) and the resistance again. This is the Mid calibration point data.

8. With TrendReader software, create a thermistor equation (using the equation wizard) from the Equation Menu. Save the equation to the logger.

Note that the accuracy of the above test procedure is primarily limited by the cumulative accuracy of the instruments you are using and how carefully you carry out the procedure. You should, however, be able to achieve accuracies within ±1.0°C under most circumstances for thermistors with R25 values of between 10k and 100k ohms. You can perform tests with thermistors of other R25 values by using dry ice (for very low temperatures down to -70°C) or an oven (for temperatures up to a maximum of 450°C).

To avoid damaging your thermistors, when calibrating, make sure to note the following:

- do not exceed the upper temperature limit rating for your high calibration point, and
- do not introduce the sensors to rapid changes in temperature (for example, from the ice bucket right into the boiling water).

1.14.3 Relative Humidity Calibration

If you want to confirm the calibration of your RH sensor or EH-020A Temperature and Relative Humidity probe, you can simply return it to your authorized sales representative or perform your own field test using the special adjustment provisions in TrendReader software.

Recommended methods of calibration include using an accurate relative humidity test chamber or by mixing saturated salt solutions. Both tests are performed at an ambient room temperature of 20 to 25°C (68 to 77°F).

RH Chamber Test

If you intend to use a Relative Humidity Test Chamber for your calibration, make sure it has been recently tested to within ±1%. The procedure to calibrate is as follows:

1. Set up your humidity data logger with a sample rate of 20 seconds and equation 38 on the RH channels. Make sure you have selected Normalized Byte data units. If you are

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calibrating an EH-020A probe, ensure it is properly connected to the logger and the external RH and temperature channels are enabled.

2. Start the test chamber at 5% RH and place your logger (SmartReader 2 or 4) or EH-020A probe into the test chamber. Wait 20 minutes.

3. Adjust the chamber to 20% RH and wait for 20 minutes. The wait is necessary to ensure the chamber has adequate time to settle at the desired level.

4. Adjust the chamber to 80% RH and wait an additional 20 minutes.

5. Remove your logger or RH module from the test chamber and backup the recorded information onto your computer. If you are working with more than one logger, use the serial number as the file name to help match the data with the logger when you make calibration adjustments.

6. Call up the logger file on your computer using TrendReader. The profile you see should reflect the test you have just performed.

7. Zoom in on the section that relates to the 20% RH level in the test chamber. Use the mouse to find the byte value recorded during the latter part of the test (refer to step 3). Record this as the "b_L" reading.

8. Zoom in on the section that relates to the 80% RH level in the test chamber. Again, use the mouse to find the byte value recorded at the end of the test (refer to step 4). Record this value as the "b_H" reading.

9. Switch to the Setup window in TrendReader software.

10. Use the following equation to calculate the "Low" calibration adjustment value:
    $Low = (63 \times b_L - 170 \times b_H) / 428$

11. For the "High" calibration adjustment value use the following equation:
    $High = 40 \times (-107 / (b_H - b_L) - 1)$

12. Now enter the same values by revising the logger file and view the corrected graphs.

13. If the results are satisfactory, save the calibration changes to the logger (remember to set the RH channel's equation number back to 71).

Saturated Salt Test
Using saturated salt solutions is the most accurate field technique for RH calibration.

To check your humidity data logger with saturated salt solutions, gather the following equipment and materials:

- Wide mouth canning jars, 1000ml with metal lids
- #9 stoppers (Fisher #14-130N)
- Powder Funnel (Fisher #10-346-5B)
- Long Stem Funnel (Fisher #10-325D)
- Cardboard or wooden box
- Styrofoam chips (or other insulating material)
- Reagent grade salts:
  1. LiCl (anhydrous), 75gm (Fisher #L-121)

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2. MgCl2 x 6H2O, 150gm (Fisher #M-33)
3. NaCl, 50gm (Fisher #S-271)

- De-ionized or distilled water, 75ml for each solution

Prepare for the saturated salt test by following these steps:

1. Use the powder funnel to carefully place the salt into the center of the jar bottom.

2. Slowly pour the water onto the mound of salt, using the long stem funnel, taking care not to splash any water or salt onto the inner walls of the jar.

3. Gently swirl the saturated solution. If the salt dissolves entirely, with no crystals remaining on the bottom, the solution is not saturated and more salt must be added. There must be crystals remaining on the bottom but they must not be exposed above the water level.

4. Put a nail through the jar lid and bend into a small hook. Tape the head of the nail (or use rubber cement) to create an airtight seal of the opening. The logger with RH sensor (or EH-020A) can be inserted into the jar by first hanging it on the nail loop then screwing on the lid to the jar.

5. The saturated salt solutions should be kept in a well insulated environment to minimize any temperature changes. The equilibrium RH over saturated salt solutions is only slightly temperature dependent. However, for close calibration work to 5% RH or better, it is important to keep the temperature of the salt solution and the air space above it identical. To ensure this, the temperature of the lab should be constant.

To perform the saturated salt test, follow these steps:

1. Setup your relative humidity logger with a sample rate of 20 seconds and equation 38 on the RH channel(s). Make sure you have selected Normalized Byte data units.

2. Place the jars into the box with 1 to 2 inches of Styrofoam chips on the bottom, then fill all remaining air spaces between the jars and the interior spaces of the box with the chips.

3. Cover the box with cardboard in which 6cm (2.5") diameter holes have been cut to allow access to the tops of the jars for insertion of the logger or RH module.

4. Place the logger with sensor or EH-020A module into the jar containing the **LiCl** solution (RH = 11%) **overnight** to eliminate any hysteresis effects.

5. Quickly insert the logger (or module) into the next solution by swapping the lids. Transfers should always be made **in the direction of higher RH conditions**. The jar should be well sealed. Allow at least two hours to get within three percent of the equilibrium RH. Repeat for next solution.

Salt	RH
$MgCl_2$	33%
NaCl	75%

6. Call up the graph on your computer using TrendReader software. The profile you see should reflect the test you have just performed.

7. Zoom in on the section that relates to the 33% RH level in the test chamber. Use the

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mouse to find the byte value recorded during the latter part of the minimum two hour test portion (refer to step 5). Record this as the "bL" reading.

8. Zoom in on the section that relates to the 75% RH level in the test chamber. Again, use the mouse to find the byte value recorded at the end of the minimum two hour test (refer to step 5). Record this value as the "bH" reading.

9. Switch to the Setup window in TrendReader software.

10. Use the following equation to calculate the "Low" calibration adjustment value:
    $Low = (71 \times b_L - 145 \times b_H) / 296$

11. For the "High" calibration adjustment value use the following equation:
    $High = 40 \times (-74 / (b_H - b_L) - 1)$

12. Now enter the same values by revising the logger file and view the corrected graphs.

13. If the results are satisfactory, save the calibration changes to the logger (remember to set the RH channel's equation number back to 71).

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1.15 APPENDIX C Thermistor Temperature Probes

Thermistor Temperature Probes

1.15.1 Thermistor Temperature Probes

The SmartReader 1, 2, 4 and 8 data loggers can record temperature from a wide variety of external thermistor temperature probes. You can use the standard thermistor probes ACR makes available or you can use your own.

1.15.2 What Are Thermistors?

Thermistors are temperature-sensitive resistors. The most common are those classified as the NTC (Negative Temperature Coefficient) type, which, at high temperatures, have a relatively low electrical resistance. At low temperatures their resistance is much higher. In between, the resistance varies with temperature at a predictable rate that can be made linear by a mathematical equation (refer to Equations in the TrendReader guide).

Thermistors provide a rugged, highly stable, and accurate means of measuring temperature. They can be used for very low temperature applications down to -80°C (-112°F) or with special probe configurations, in environments up to 450°C (850°F).

Thermistors with consistent properties, for a given type, are readily available. These interchangeable thermistors can be substituted without recalibrating the logger.

1.15.3 ET Series Temperature Probes

The ET Series External Temperature Probes provide added versatility to the temperature measuring capabilities of your SmartReader 1, 2, 4 and 8 data loggers. Accurate, interchangeable and suitable for various defined temperature ranges, they interface easily to the terminal connector block on each logger. Each ET Series Temperature Probe consists of a NTC thermistor potted into the tip of a short length of stainless steel tubing.

Equations
Each ET series thermistor probe is associated with a standard linearizing equation in TrendReader software. The equation converts the resistance values of the thermistor to accurate temperature readings depending on the specific characteristics of the thermistor type.

Why the Different Types?
Individual thermistor types are most effectively used over specific and defined temperature ranges in order to maximize measurement accuracy and resolution. In addition, some

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thermistor probes are constructed to accommodate special environmental or application conditions.

There are six different types of ET Series temperature probes available that cover a wide range of operation.

- **ET-016 General Purpose Temperature Probe** is best suited for general purpose temperature measurements centered on ambient room temperature.
- **ET-004 Low Temperature Probe** is ideal for sub-zero temperature measurements and consists of a handle with a stainless steel penetration probe (it can be used, among other applications, to monitor semi-solid frozen foods).
- **ET-081 High Temperature Probe** is best suited for higher temperature centered on 77°C (170°F).
- **ET-086 Oven Temperature Probe** is designed for even higher measurement centered on 150°C (300°F).
- **ET-016-STP** is used to monitor skin temperature on human and animals.
- **ET-016-SMP** is used to measure pipe surface temperature. It wraps around any pipe less than 2" in diameter.

If your needs for temperature measuring do not quite fit the ET series profile, you may consider using a different type of probe. The Custom Probes section in this chapter describes how you can work with other commercially-available thermistor probes from many different suppliers.

1.15.4 Setup and Use

ET series thermistor probes are easy to use and setup with your loggers. To make a probe work with your particular logger, follow the instructions for using remote thermistor probes in the chapter that deals with your SmartReader model. After connecting your thermistor, make sure:

- the proper temperature equation is loaded for each enabled channel. If you do not use the correct equation, you will end up producing misleading readings.
- to check operation of your external probes before heading out in the field by viewing the Realtime values in TrendReader software.

Probe	Range	Equation
ET-016	-35 to 95°C (-30 to 200°F)	45
ET-004	-60 to 55°C (-75 to 130°F)	46
ET-081	10 to 170°C (50 to 335°F)	47
ET-086	70 to 255°C (155 to 490°F)	48

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Extending Cable Lengths
If you find the standard length of your ET Series Temperature Probe cable is not long enough for your intended application, you can extend the cable yourself up to 30m (100ft). Use 2-conductor 22-gauge shielded wire. To prevent measurement errors, make sure the connections are properly insulated and well protected from moisture.

Applications
The ET Series Temperature Probes lend themselves to a wide range of applications. For example, to log temperatures from pipes you can insert your ET Probe in an existing thermometer well or strap the tip of the probe to the pipe for a surface conduction temperature (for best thermal conductivity, epoxy the probe tip directly to the pipe and replace the pipe insulation back over top). You can also easily measure duct temperatures by simply drilling a hole in the duct and inserting your ET probe.

1.15.5 Specifications

ET-016 General Purpose Probe

Description:	NTC thermistor and cable potted into the end of a 25mm (1") long by 5mm (3/16") diameter cylindrical stainless steel tip.
Equation:	45
R25 Value:	10k ohms
Range:	-35 to 95°C (-30 to 200°F)
Max. Temp.:	150°C (300°F)
Resolution:	Refer to Figure C-1
Accuracy:	±0.2°C (±0.36°F) from the temperature values listed in Table C-1 over the range of 0 to 70°C (32 to 158°F) ±0.5°C (±0.9°F) from -35 to 0°C (-30 to 32°F). ±0.5°C (±0.9°F) from 70 to 120°C (158 to 248°F)
Cable:	6 m (20ft) standard length with a Teflon® protective jacket;

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red and black leads are stripped and tinned.

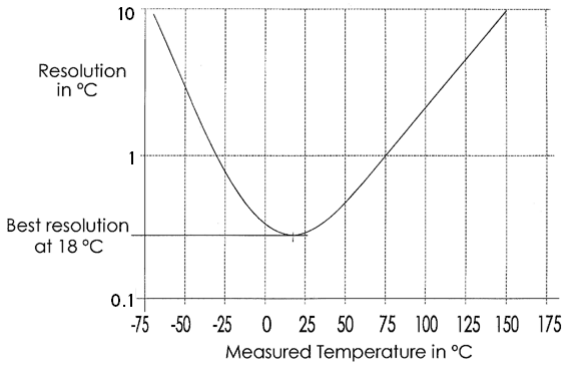

Figure C-1: Resolution Chart for the ET-016 Probe

ET-016: Extended exposure to temperatures above 70°C may result in permanent resistance drift, resulting in loss of ±0.2°C tolerance over the 0 to 70°C temperature range. Extended exposure to temperatures below 0°C may result in some mechanical damage due to thermal contraction effects.

ET-004 Low Temperature Probe

Description:	NTC thermistor and cable potted into the end of a 89mm (3½ ") long tapered stainless steel penetration tip with 89mm (3½ ") long by 19mm (¾") diameter tapered plastic handle.
R25 Value:	2,252 ohms
Equation:	46
Range:	-60 to 55°C (-75 to 130°F)
Resolution:	Refer to Figure C-2
Accuracy:	±0.2°C (±0.4°F) from 0 to 55°C (32 to 113°F) ±0.6°C (±1.1°F) from -50 to -30°C (-58 to -22°F) ±0.3°C (±0.54°F) from -30 to 0°C (-22 to 32°F)
Cable:	3m (10ft) length wtih a Teflon® protective jacket; red and

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black leads are stripped and tinned.

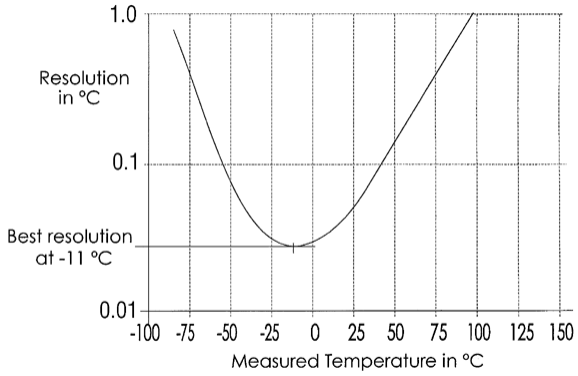

Figure C-2: Resolution Chart for the ET-004 Probe

ET-081 High Temperature Probe

Description:	NTC thermistor and cable potted into the end of a 22mm (7/8") long by 5mm (3/16") diameter nickel-plated eyelet.
R25 Value:	100k ohms
Equation:	47
Range:	10 to 170°C (50 to 335°F)
Max. Temp.:	190°C (375°F)
Resolution:	Refer to Figure C-3
Accuracy:	±0.5°C (0.9°F) from the temperature values listed in Table C-1 over the range of 10 to 170°C (50 to 335°F).
Cable:	6m (20ft) standard length with twisted-pair Teflon® insulated

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wire; red and white leads are stripped and tinned.

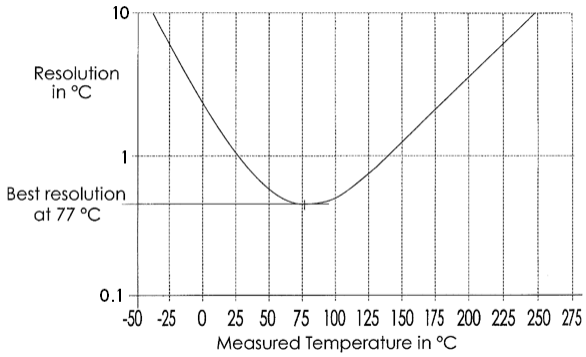

Figure C-3: Resolution Chart for the ET-081 Probe

ET-086 Oven Temperature Probe

Description:	NTC thermistor and cable potted into the end of a 22mm (7/8") long by 5.5 mm (7/32") diameter nickel-plated eyelet.
R125 Value:	26,266 ohms
Equation:	48
Range:	70 to 255°C (155 to 490°F)
Max. Temp.:	275°C (525°F)
Resolution:	Refer to Figure C-4
Accuracy:	±1°C (1.8°F) from the temperature values listed in Table C-1 over the range of 70 to 255°C (155 to 490°F)
Cable:	6m (20ft) standard length with twisted-pair moisture-proof Teflon®- coated glass yarn wire; white leads are stripped and

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tinned.

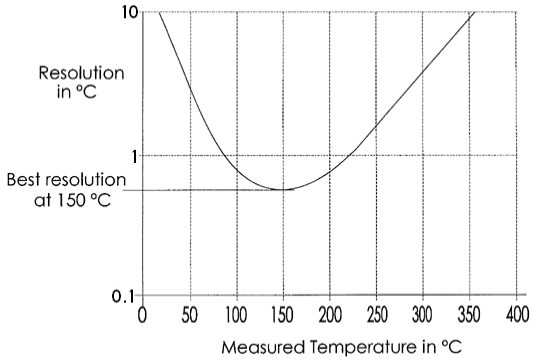

Figure C-4: Resolution Chart for the ET-086 Probe

1.15.6 Resistance vs. Temperature Tables

The following table lists the Resistance vs. Temperature characteristics of the ET series thermistor probes as they relate to use with the SmartReader 1, 2, 4 and 8 loggers.

For each thermistor probe model, the table documents the complete set of temperature readings and corresponding thermistor resistances possible from the logger's 8-bit processor (256 byte values).

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Table C-1: Temperature-Resistance Values for ET Series Probes

Byte Number	Probe Model No. Resistance (ohms)	ET-016 °C	ET-004 °C	ET-081 °C	ET-086 °C	ET-016 °F	ET-004 °F	ET-081 °F	ET-086 °F
255	5,000,000	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
254	2,540,000	-67.5	-84.7	-35.3	6.0	-89.4	-120.5	-31.6	42.8
253	1,265,000	-58.6	-76.9	-24.2	20.0	-73.5	-106.5	-11.6	68.0
252	840,000	-53.1	-72.2	-17.3	28.8	-63.6	-97.9	0.9	83.8
251	627,500	-49.1	-68.6	-12.1	35.3	-56.3	-91.5	10.2	95.5
250	500,000	-45.8	-65.8	-8.0	40.5	-50.5	-86.5	17.7	104.9
249	415,000	-43.1	-63.5	-4.5	44.9	-45.6	-82.3	23.9	112.8
248	354,286	-40.8	-61.5	-1.5	48.7	-41.4	-78.6	29.4	119.7
247	308,750	-38.7	-59.7	1.2	52.1	-37.7	-75.4	34.2	125.8
246	273,333	-36.8	-58.1	3.6	55.2	-34.3	-72.5	38.5	131.3
245	245,000	-35.1	-56.6	5.8	57.9	-31.3	-69.9	42.5	136.3
244	221,818	-33.6	-55.3	7.8	60.5	-28.5	-67.5	46.1	140.9
243	202,500	-32.2	-54.1	9.7	62.9	-25.9	-65.3	49.5	145.2
242	186,154	-30.8	-52.9	11.5	65.1	-23.5	-63.2	52.6	149.2
241	172,143	-29.6	-51.8	13.1	67.2	-21.2	-61.3	55.6	152.9
240	160,000	-28.4	-50.8	14.7	69.2	-19.1	-59.5	58.4	156.5
239	149,375	-27.2	-49.8	16.1	71.0	-17.0	-57.7	61.0	159.9
238	140,000	-26.2	-48.9	17.5	72.8	-15.1	-56.1	63.6	163.1
237	131,667	-25.2	-48.1	18.9	74.5	-13.3	-54.5	66.0	166.1
236	124,211	-24.2	-47.2	20.2	76.1	-11.5	-53.0	68.3	169.1
235	117,500	-23.3	-46.4	21.4	77.7	-9.9	-51.6	70.5	171.9
234	111,429	-22.4	-45.7	22.6	79.2	-8.3	-50.2	72.6	174.6
233	105,909	-21.5	-44.9	23.7	80.7	-6.7	-48.9	74.7	177.2
232	100,870	-20.7	-44.2	24.8	82.1	-5.2	-47.6	76.7	179.7
231	96,250	-19.9	-43.5	25.9	83.4	-3.7	-46.4	78.6	182.1
230	92,000	-19.1	-42.9	26.9	84.7	-2.3	-45.2	80.5	184.5
229	88,077	-18.3	-42.2	27.9	86.0	-1.0	-44.0	82.3	186.8
228	84,444	-17.6	-41.6	28.9	87.2	0.3	-42.9	84.0	189.0
227	81,071	-16.9	-41.0	29.9	88.5	1.6	-41.8	85.7	191.2
226	77,931	-16.2	-40.4	30.8	89.6	2.9	-40.7	87.4	193.3
225	75,000	-15.5	-39.8	31.7	90.8	4.1	-39.7	89.0	195.4
224	72,258	-14.8	-39.3	32.6	91.9	5.3	-38.7	90.6	197.4
223	69,688	-14.2	-38.7	33.4	93.0	6.5	-37.7	92.2	199.4
222	67,273	-13.6	-38.2	34.3	94.1	7.6	-36.7	93.7	201.4
221	65,000	-12.9	-37.7	35.1	95.1	8.7	-35.8	95.2	203.2
220	62,857	-12.3	-37.2	35.9	96.2	9.8	-34.9	96.7	205.1
219	60,833	-11.7	-36.7	36.7	97.2	10.9	-34.0	98.1	206.9
218	58,919	-11.2	-36.2	37.5	98.2	11.9	-33.1	99.5	208.7
217	57,105	-10.6	-35.7	38.3	99.1	12.9	-32.2	100.9	210.5
216	55,385	-10.0	-35.2	39.0	100.1	14.0	-31.4	102.2	212.2
215	53,750	-9.5	-34.7	39.8	101.1	14.9	-30.5	103.6	213.9
214	52,195	-8.9	-34.3	40.5	102.0	15.9	-29.7	104.9	215.6
213	50,714	-8.4	-33.8	41.2	102.9	16.9	-28.9	106.2	217.2
212	49,302	-7.9	-33.4	41.9	103.8	17.8	-28.1	107.4	218.8
211	47,955	-7.4	-32.9	42.6	104.7	18.8	-27.3	108.7	220.4
210	46,667	-6.8	-32.5	43.3	105.6	19.7	-26.5	109.9	222.0
209	45,435	-6.3	-32.1	44.0	106.4	20.6	-25.8	111.2	223.6
208	44,255	-5.8	-31.7	44.6	107.3	21.5	-25.0	112.4	225.1
207	43,125	-5.4	-31.3	45.3	108.1	22.4	-24.3	113.5	226.6
206	42,041	-4.9	-30.9	46.0	109.0	23.2	-23.5	114.7	228.1
205	41,000	-4.4	-30.5	46.6	109.8	24.1	-22.8	115.9	229.6
204	40,000	-3.9	-30.1	47.2	110.6	24.9	-22.1	117.0	231.1
203	39,038	-3.5	-29.7	47.9	111.4	25.8	-21.4	118.2	232.5
202	38,113	-3.0	-29.3	48.5	112.2	26.6	-20.7	119.3	233.9
201	37,222	-2.5	-28.9	49.1	113.0	27.4	-20.0	120.4	235.3
200	36,364	-2.1	-28.5	49.7	113.8	28.2	-19.3	121.5	236.8
199	35,536	-1.7	-28.1	50.3	114.5	29.0	-18.6	122.6	238.1
198	34,737	-1.2	-27.8	50.9	115.3	29.8	-18.0	123.7	239.5
197	33,966	-0.8	-27.4	51.5	116.0	30.6	-17.3	124.7	240.9
196	33,220	-0.3	-27.0	52.1	116.8	31.4	-16.7	125.8	242.2
195	32,500	0.1	-26.7	52.7	117.5	32.2	-16.0	126.9	243.6
194	31,803	0.5	-26.3	53.3	118.3	32.9	-15.4	127.9	244.9
193	31,129	0.9	-26.0	53.8	119.0	33.7	-14.7	128.9	246.2
192	30,476	1.4	-25.6	54.4	119.7	34.4	-14.1	130.0	247.5

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Byte Number	Probe Model No. Resistance (ohms)	ET-016 °C	ET-004 °C	ET-081 °C	ET-086 °C	ET-016 °F	ET-004 °F	ET-081 °F	ET-086 °F
191	29,844	1.8	-25.3	55.0	120.5	35.2	-13.5	131.0	248.8
190	29,231	2.2	-24.9	55.5	121.2	35.9	-12.9	132.0	250.1
189	28,636	2.6	-24.6	56.1	121.9	36.7	-12.2	133.0	251.4
188	28,060	3.0	-24.2	56.7	122.6	37.4	-11.6	134.0	252.7
187	27,500	3.4	-23.9	57.2	123.3	38.1	-11.0	135.0	253.9
186	26,957	3.8	-23.6	57.8	124.0	38.8	-10.4	136.0	255.2
185	26,429	4.2	-23.2	58.3	124.7	39.5	-9.8	136.9	256.4
184	25,915	4.6	-22.9	58.8	125.4	40.3	-9.2	137.9	257.7
183	25,417	5.0	-22.6	59.4	126.1	41.0	-8.6	138.9	258.9
182	24,932	5.4	-22.2	59.9	126.8	41.7	-8.0	139.8	260.2
181	24,459	5.8	-21.9	60.4	127.4	42.4	-7.5	140.8	261.4
180	24,000	6.1	-21.6	61.0	128.1	43.1	-6.9	141.8	262.6
179	23,553	6.5	-21.3	61.5	128.8	43.7	-6.3	142.7	263.8
178	23,117	6.9	-21.0	62.0	129.4	44.4	-5.7	143.6	265.0
177	22,692	7.3	-20.6	62.5	130.1	45.1	-5.1	144.6	266.2
176	22,278	7.7	-20.3	63.1	130.8	45.8	-4.6	145.5	267.4
175	21,875	8.0	-20.0	63.6	131.4	46.5	-4.0	146.4	268.6
174	21,481	8.4	-19.7	64.1	132.1	47.1	-3.5	147.4	269.8
173	21,098	8.8	-19.4	64.6	132.8	47.8	-2.9	148.3	271.0
172	20,723	9.2	-19.1	65.1	133.4	48.5	-2.3	149.2	272.1
171	20,357	9.5	-18.8	65.6	134.1	49.1	-1.8	150.1	273.3
170	20,000	9.9	-18.5	66.1	134.7	49.8	-1.2	151.0	274.5
169	19,651	10.3	-18.2	66.6	135.4	50.5	-0.7	152.0	275.6
168	19,310	10.6	-17.8	67.1	136.0	51.1	-0.1	152.9	276.8
167	18,977	11.0	-17.5	67.7	136.6	51.8	0.4	153.8	278.0
166	18,652	11.4	-17.2	68.2	137.3	52.4	1.0	154.7	279.1
165	18,333	11.7	-16.9	68.7	137.9	53.1	1.5	155.6	280.3
164	18,022	12.1	-16.6	69.2	138.6	53.7	2.1	156.5	281.4
163	17,717	12.4	-16.3	69.7	139.2	54.4	2.6	157.4	282.6
162	17,419	12.8	-16.0	70.1	139.8	55.0	3.1	158.3	283.7
161	17,128	13.2	-15.7	70.6	140.5	55.7	3.7	159.2	284.8
160	16,842	13.5	-15.4	71.1	141.1	56.3	4.2	160.1	286.0
159	16,563	13.9	-15.1	71.6	141.7	57.0	4.7	160.9	287.1
158	16,289	14.2	-14.8	72.1	142.4	57.6	5.3	161.8	288.3
157	16,020	14.6	-14.6	72.6	143.0	58.2	5.8	162.7	289.4
156	15,758	14.9	-14.3	73.1	143.6	58.9	6.3	163.6	290.5
155	15,500	15.3	-14.0	73.6	144.3	59.5	6.9	164.5	291.7
154	15,248	15.6	-13.7	74.1	144.9	60.2	7.4	165.4	292.8
153	15,000	16.0	-13.4	74.6	145.5	60.8	7.9	166.3	293.9
152	14,757	16.3	-13.1	75.1	146.1	61.4	8.5	167.1	295.1
151	14,519	16.7	-12.8	75.6	146.8	62.1	9.0	168.0	296.2
150	14,286	17.1	-12.5	76.1	147.4	62.7	9.5	168.9	297.3
149	14,057	17.4	-12.2	76.6	148.0	63.3	10.0	169.8	298.5
148	13,832	17.8	-11.9	77.0	148.7	64.0	10.6	170.7	299.6
147	13,611	18.1	-11.6	77.5	149.3	64.6	11.1	171.6	300.7
146	13,394	18.5	-11.3	78.0	149.9	65.2	11.6	172.4	301.8
145	13,182	18.8	-11.0	78.5	150.5	65.9	12.1	173.3	303.0
144	12,973	19.2	-10.7	79.0	151.2	66.5	12.7	174.2	304.1
143	12,768	19.5	-10.4	79.5	151.8	67.1	13.2	175.1	305.2
142	12,566	19.9	-10.2	80.0	152.4	67.8	13.7	176.0	306.4
141	12,368	20.2	-9.9	80.5	153.1	68.4	14.2	176.9	307.5
140	12,174	20.6	-9.6	81.0	153.7	69.0	14.8	177.7	308.6
139	11,983	20.9	-9.3	81.5	154.3	69.7	15.3	178.6	309.8
138	11,795	21.3	-9.0	82.0	155.0	70.3	15.8	179.5	310.9
137	11,610	21.6	-8.7	82.4	155.6	70.9	16.3	180.4	312.1
136	11,429	22.0	-8.4	82.9	156.2	71.6	16.9	181.3	313.2
135	11,250	22.3	-8.1	83.4	156.9	72.2	17.4	182.2	314.3
134	11,074	22.7	-7.8	83.9	157.5	72.8	17.9	183.1	315.5
133	10,902	23.0	-7.5	84.4	158.1	73.5	18.5	184.0	316.6
132	10,732	23.4	-7.2	84.9	158.8	74.1	19.0	184.9	317.8
131	10,565	23.7	-6.9	85.4	159.4	74.7	19.5	185.8	318.9
130	10,400	24.1	-6.6	85.9	160.0	75.4	20.0	186.7	320.1
129	10,238	24.5	-6.3	86.4	160.7	76.0	20.6	187.6	321.2
128	10,079	24.8	-6.1	86.9	161.3	76.7	21.1	188.5	322.4

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Byte Number	Probe Model No. Resistance (ohms)	ET-016 °C	ET-004 °C	ET-081 °C	ET-086 °C	ET-016 °F	ET-004 °F	ET-081 °F	ET-086 °F
127	9,922	25.2	-5.8	87.4	162.0	77.3	21.6	189.4	323.6
126	9,767	25.5	-5.5	87.9	162.6	78.0	22.2	190.3	324.7
125	9,615	25.9	-5.2	88.4	163.3	78.6	22.7	191.2	325.9
124	9,466	26.3	-4.9	88.9	163.9	79.3	23.2	192.1	327.1
123	9,318	26.6	-4.6	89.5	164.6	79.9	23.8	193.0	328.2
122	9,173	27.0	-4.3	90.0	165.2	80.6	24.3	193.9	329.4
121	9,030	27.3	-4.0	90.5	165.9	81.2	24.9	194.9	330.6
120	8,889	27.7	-3.7	91.0	166.5	81.9	25.4	195.8	331.8
119	8,750	28.1	-3.4	91.5	167.2	82.5	25.9	196.7	333.0
118	8,613	28.4	-3.1	92.0	167.9	83.2	26.5	197.7	334.2
117	8,478	28.8	-2.8	92.5	168.5	83.8	27.0	198.6	335.4
116	8,345	29.2	-2.5	93.1	169.2	84.5	27.6	199.5	336.6
115	8,214	29.5	-2.2	93.6	169.9	85.2	28.1	200.5	337.8
114	8,085	29.9	-1.8	94.1	170.6	85.8	28.7	201.4	339.0
113	7,958	30.3	-1.5	94.7	171.2	86.5	29.2	202.4	340.2
112	7,832	30.7	-1.2	95.2	171.9	87.2	29.8	203.3	341.5
111	7,708	31.0	-0.9	95.7	172.6	87.9	30.3	204.3	342.7
110	7,586	31.4	-0.6	96.3	173.3	88.5	30.9	205.3	343.9
109	7,466	31.8	-0.3	96.8	174.0	89.2	31.5	206.2	345.2
108	7,347	32.2	0.0	97.3	174.7	89.9	32.0	207.2	346.4
107	7,230	32.6	0.3	97.9	175.4	90.6	32.6	208.2	347.7
106	7,114	32.9	0.7	98.4	176.1	91.3	33.2	209.2	349.0
105	7,000	33.3	1.0	99.0	176.8	92.0	33.7	210.1	350.2
104	6,887	33.7	1.3	99.5	177.5	92.7	34.3	211.1	351.5
103	6,776	34.1	1.6	100.1	178.2	93.4	34.9	212.1	352.8
102	6,667	34.5	1.9	100.6	178.9	94.1	35.5	213.2	354.1
101	6,558	34.9	2.3	101.2	179.7	94.8	36.1	214.2	355.4
100	6,452	35.3	2.6	101.8	180.4	95.5	36.7	215.2	356.7
99	6,346	35.7	2.9	102.3	181.1	96.2	37.2	216.2	358.0
98	6,242	36.1	3.2	102.9	181.9	97.0	37.8	217.2	359.4
97	6,139	36.5	3.6	103.5	182.6	97.7	38.4	218.3	360.7
96	6,038	36.9	3.9	104.1	183.4	98.4	39.0	219.3	362.0
95	5,938	37.3	4.2	104.7	184.1	99.2	39.6	220.4	363.4
94	5,839	37.7	4.6	105.2	184.9	99.9	40.3	221.4	364.8
93	5,741	38.1	4.9	105.8	185.6	100.7	40.9	222.5	366.1
92	5,644	38.6	5.3	106.4	186.4	101.4	41.5	223.6	367.5
91	5,549	39.0	5.6	107.0	187.2	102.2	42.1	224.7	368.9
90	5,455	39.4	6.0	107.7	188.0	102.9	42.7	225.8	370.3
89	5,361	39.8	6.3	108.3	188.8	103.7	43.4	226.9	371.8
88	5,269	40.3	6.7	108.9	189.5	104.5	44.0	228.0	373.2
87	5,179	40.7	7.0	109.5	190.3	105.2	44.6	229.1	374.6
86	5,089	41.1	7.4	110.1	191.2	106.0	45.3	230.2	376.1
85	5,000	41.6	7.7	110.8	192.0	106.8	45.9	231.4	377.6
84	4,912	42.0	8.1	111.4	192.8	107.6	46.6	232.5	379.0
83	4,826	42.5	8.5	112.1	193.6	108.4	47.2	233.7	380.5
82	4,740	42.9	8.8	112.7	194.5	109.3	47.9	234.9	382.1
81	4,655	43.4	9.2	113.4	195.3	110.1	48.6	236.1	383.6
80	4,571	43.8	9.6	114.0	196.2	110.9	49.3	237.3	385.1
79	4,489	44.3	10.0	114.7	197.0	111.7	49.9	238.5	386.7
78	4,407	44.8	10.4	115.4	197.9	112.6	50.6	239.7	388.3
77	4,326	45.2	10.7	116.1	198.8	113.4	51.3	240.9	389.8
76	4,246	45.7	11.1	116.8	199.7	114.3	52.0	242.2	391.4
75	4,167	46.2	11.5	117.5	200.6	115.2	52.8	243.4	393.1
74	4,088	46.7	11.9	118.2	201.5	116.1	53.5	244.7	394.7
73	4,011	47.2	12.3	118.9	202.4	116.9	54.2	246.0	396.4
72	3,934	47.7	12.7	119.6	203.4	117.8	54.9	247.3	398.1
71	3,859	48.2	13.2	120.3	204.3	118.8	55.7	248.6	399.8
70	3,784	48.7	13.6	121.1	205.3	119.7	56.4	250.0	401.5
69	3,710	49.2	14.0	121.8	206.2	120.6	57.2	251.3	403.2
68	3,636	49.7	14.4	122.6	207.2	121.5	58.0	252.7	405.0
67	3,564	50.3	14.8	123.4	208.2	122.5	58.7	254.1	406.8
66	3,492	50.8	15.3	124.2	209.2	123.5	59.5	255.5	408.6
65	3,421	51.4	15.7	124.9	210.3	124.4	60.3	256.9	410.5
64	3,351	51.9	16.2	125.7	211.3	125.4	61.1	258.3	412.3

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Byte Number	Probe Model No. Resistance (ohms)	ET-016 °C	ET-004 °C	ET-081 °C	ET-086 °C	ET-016 °F	ET-004 °F	ET-081 °F	ET-086 °F
63	3,281	52.5	16.6	126.6	212.3	126.4	61.9	259.8	414.2
62	3,212	53.0	17.1	127.4	213.4	127.5	62.8	261.3	416.1
61	3,144	53.6	17.6	128.2	214.5	128.5	63.6	262.8	418.1
60	3,077	54.2	18.0	129.1	215.6	129.5	64.5	264.3	420.1
59	3,010	54.8	18.5	129.9	216.7	130.6	65.3	265.9	422.1
58	2,944	55.4	19.0	130.8	217.9	131.7	66.2	267.5	424.1
57	2,879	56.0	19.5	131.7	219.0	132.8	67.1	269.1	426.2
56	2,814	56.6	20.0	132.6	220.2	133.9	68.0	270.7	428.3
55	2,750	57.2	20.5	133.6	221.4	135.0	68.9	272.4	430.5
54	2,687	57.9	21.0	134.5	222.6	136.2	69.8	274.1	432.7
53	2,624	58.5	21.6	135.4	223.8	137.4	70.8	275.8	434.9
52	2,562	59.2	22.1	136.4	225.1	138.5	71.8	277.6	437.2
51	2,500	59.9	22.6	137.4	226.4	139.8	72.7	279.4	439.5
50	2,439	60.6	23.2	138.4	227.7	141.0	73.7	281.2	441.8
49	2,379	61.3	23.8	139.5	229.0	142.3	74.8	283.0	444.3
48	2,319	62.0	24.3	140.5	230.4	143.5	75.8	284.9	446.7
47	2,260	62.7	24.9	141.6	231.8	144.9	76.9	286.9	449.2
46	2,201	63.4	25.5	142.7	233.2	146.2	77.9	288.9	451.8
45	2,143	64.2	26.1	143.8	234.7	147.6	79.0	290.9	454.4
44	2,085	65.0	26.8	145.0	236.2	149.0	80.2	293.0	457.1
43	2,028	65.8	27.4	146.2	237.7	150.4	81.3	295.1	459.8
42	1,972	66.6	28.1	147.4	239.3	151.8	82.5	297.2	462.7
41	1,916	67.4	28.7	148.6	240.9	153.3	83.7	299.5	465.5
40	1,860	68.3	29.4	149.9	242.5	154.9	84.9	301.8	468.5
39	1,806	69.1	30.1	151.2	244.2	156.4	86.2	304.1	471.5
38	1,751	70.0	30.8	152.5	245.9	158.0	87.5	306.5	474.7
37	1,697	70.9	31.6	153.9	247.7	159.7	88.8	309.0	477.9
36	1,644	71.9	32.3	155.3	249.5	161.4	90.2	311.5	481.2
35	1,591	72.9	33.1	156.7	251.4	163.1	91.6	314.1	484.6
34	1,538	73.9	33.9	158.2	253.4	164.9	93.1	316.8	488.1
33	1,486	74.9	34.7	159.8	255.4	166.8	94.5	319.6	491.7
32	1,435	76.0	35.6	161.4	257.5	168.7	96.1	322.5	495.5
31	1,384	77.1	36.5	163.1	259.6	170.7	97.7	325.5	499.4
30	1,333	78.2	37.4	164.8	261.9	172.7	99.3	328.6	503.4
29	1,283	79.4	38.3	166.6	264.2	174.9	101.0	331.8	507.5
28	1,233	80.6	39.3	168.4	266.6	177.1	102.8	335.1	511.9
27	1,184	81.9	40.3	170.3	269.1	179.3	104.6	338.6	516.4
26	1,135	83.2	41.4	172.3	271.7	181.7	106.5	342.2	521.1
25	1,087	84.5	42.5	174.4	274.4	184.2	108.5	346.0	526.0
24	1,039	86.0	43.6	176.6	277.3	186.8	110.5	349.9	531.1
23	991	87.5	44.8	178.9	280.3	189.5	112.7	354.0	536.5
22	944	89.1	46.1	181.3	283.4	192.3	114.9	358.4	542.2
21	897	90.7	47.4	183.8	286.7	195.3	117.3	362.9	548.1
20	851	92.4	48.8	186.5	290.2	198.4	119.8	367.7	554.4
19	805	94.3	50.2	189.4	293.9	201.7	122.4	372.8	561.1
18	759	96.2	51.8	192.4	297.9	205.2	125.2	378.3	568.2
17	714	98.3	53.4	195.6	302.1	208.9	128.1	384.0	575.7
16	669	100.5	55.1	199.0	306.6	212.9	131.3	390.2	583.8
15	625	102.9	57.0	202.7	311.4	217.2	134.6	396.9	592.5
14	581	105.4	59.0	206.7	316.7	221.8	138.2	404.1	602.0
13	537	108.2	61.2	211.1	322.4	226.7	142.2	411.9	612.2
12	494	111.2	63.6	215.8	328.6	232.2	146.4	420.5	623.5
11	451	114.5	66.2	221.1	335.5	238.1	151.1	429.9	635.9
10	408	118.2	69.1	226.9	343.2	244.8	156.3	440.5	649.8
9	366	122.3	72.3	233.5	351.9	252.2	162.1	452.4	665.5
8	324	127.0	75.9	241.1	361.9	260.7	168.7	466.0	683.4
7	282	132.5	80.2	249.9	373.5	270.4	176.3	481.8	704.4
6	241	138.9	85.1	260.4	387.4	282.0	185.2	500.7	729.4
5	200	146.7	91.1	273.3	404.5	296.0	196.0	523.9	760.2
4	159	156.6	98.7	289.8	426.6	313.8	209.7	553.6	799.8
3	119	169.9	108.9	312.5	457.0	337.9	228.0	594.5	854.5
2	79	190.1	124.1	347.6	504.2	374.2	255.4	657.7	939.5
1	39	228.8	152.9	417.8	599.8	443.9	307.1	784.0	1111.6
0	10	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A

1.15.7 Custom Probes

Obtaining thermistors through specialty suppliers allows you wider flexibility in the number of possible probe assemblies for your specific applications. That way, if you have special

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surface, penetration, pipe well, or immersion sensing applications, you can usually get off-the-shelf or even custom probes to suit. Contact your dealer for recommendations.

Writing Your Own Thermistor Equations
Each thermistor temperature probe you use with SmartReader data loggers must be associated with a standard or custom equation in the TrendReader software. This equation translates the internal digital logger readings for the specific thermistor, or thermistor type, into the units of your choice (e.g., degrees Celsius or Fahrenheit).

TrendReader software includes a function that can automatically create custom equations for use with your own thermistors. See Equations in the TrendReader guide.

1.15.8 Where to Get Thermistors

Thermistor temperature sensors and probe assemblies are available from several different sources in a wide variety of configurations. You can obtain thermistors just by themselves and assemble them into your own probes, or order them completely pre-assembled. Some manufacturers will have off-the-shelf availability of products (or be able to guide you to one of their distributors who does) or else provide you with a custom probe configuration to suit your specific need.

1.15.9 How to Choose Thermistors

Obtaining thermistors can be confusing. To help, here are a variety of terms and how they relate to using them with your SmartReader data loggers.

Interchangeable
Interchangeable is a term that refers to sensors that can be freely used with the same linearizing equation (the type of equation that TrendReader software uses to convert resistance readings into temperature) and still produce accurate readings within a certain degree of accuracy (tolerance). For example, five thermistors with an interchangeability tolerance of ±0.2°C should be able to produce readings within ±0.2°C. Most interchangeable thermistors are available in tolerances ranging from ±1.0 down to ±0.05°C within a defined temperature range (for example, 0 to 70°C). This interchangeability can usually be extended well beyond this range, however, the tolerance degrades.

Interchangeable thermistors are strongly recommended if the sensors are intended for use on more than one SmartReader channel or data logger. When acquiring interchangeable thermistors,make sure to request the specific resistance-temperature data that you will need for calibration purposes.

Tolerance
Tolerance refers to the amount of uncertainty (expressed as either a percentage of the resistance value or as a temperature) to expect from a particular type of thermistor. For interchangeable thermistors, tolerance is given over a specific range of temperatures (for example, *±1%, or ±0.2°C over a range of 0 to 70°C*).

You can also use non-interchangeable thermistors with far looser tolerances (for example, 5% or 20%), however, then you will be required to perform your own temperature calibration (see

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Calibrating Thermistors) and each one must be associated with a particular unique equation. Note that non-interchangeable thermistors are specified with a tolerance applicable at a single reference point only.

NTC and PTC

By far the most common types of thermistors have a negative temperature coefficient (NTC). These are the types that you should obtain for accurate temperature sensing. Positive Temperature Coefficient (PTC) thermistors are not applicable for use with SmartReader data loggers.

Linear Thermistors

Linear thermistors are actually two or more separate thermistors, combined together, for use with a resistor set. The result is a "thermistor" with a response curve that approaches a straight line. Because TrendReader software can accurately linearize the thermistor curve using the Steinhart-Hart equation, linear thermistors are not necessary, nor applicable, for use with SmartReader data loggers.

Resistance at 25°C

One of the main considerations when choosing a thermistor is its resistance characteristics. Selecting the right one will help you maximize the resolution and accuracy of your SmartReader data logger measurements.

Your goal here should be to choose a thermistor that has a resistance of approximately 10k ohms at the midpoint of the temperature range in which you want to monitor. The graph in Figure C-5 shows how the temperature resolution from your loggers changes at different resistance values. From the graph you can see that the best resolution occurs at 10k ohms.

A good indicator of this is the thermistor's $\mathbf{R}_{25}$ rating which is a standard value identifying its resistance measured at 25°C. To decide which $\mathbf{R}_{25}$ value is best for your applications first determine the midpoint of the temperature range you want to monitor. Then refer to Figure C-6 which shows the best $\mathbf{R}_{25}$ values for different temperature midpoints.

If you wish to measure temperature centered on the boiling point of water (100°C), for example, the best thermistor to use would have a resistance of approximately 300k ohms at 25°C (and thus approximately 10k ohms at 100°C).

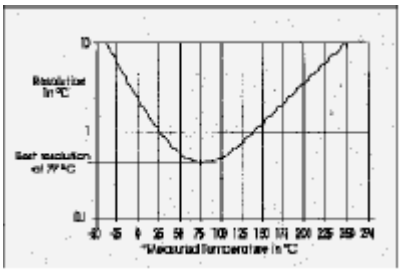

Figure C-5: Thermistor Resolution Chart

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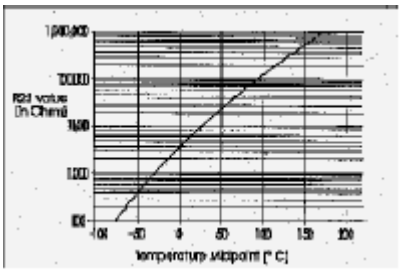

Figure C-6: Choosing an R_{25} Value

Resistance Curves
Always request the Resistance-Temperature data of the thermistors you obtain. If you are getting "interchangeable" sensors, this data will make initial calibration very easy.

1.15.10 Probe Assemblies

Because unprotected thermistors are poorly suited to most temperature measurements, they must be mounted in some type of probe assembly.

A probe may simply be a thermistor on the end of a cable protected by a special potting compound, or a drilled-out bolt for installation into a tapped hole or pipe well. An ET Series Temperature Probe is simply a thermistor attached to the end of a length of high-temperature cable, then mounted, with special potting, into the end of a short length of stainless steel tubing. Endless possibilities exist. Many thermistor manufacturers offer custom probe assemblies to fit specific applications. Thermistor distributors such as Omega® usually have standard thermistor probe assemblies.

When making a probe, the thermistor should be soldered to a length of wire or cable and inserted into the probe, generally with epoxy in the probe tip to give mechanical strength and to create better thermal contact with the probe. Additional epoxy is used to seal the back end. Make sure not to get any air bubbles into the probe or the pressure resulting from high temperature monitoring may destroy the potting.

Types of Cables
Thermistors require 2-conductor cables. There are no limitations here as to which cable you can use as long as the environment you intend to use the probes in will not exceed the specific temperature ratings of the cable itself. A good cable to use is 22-gauge stranded with high-temperature Teflon® or Kynar™ insulated leads.

Shielded cable is not usually required unless the sensors will be used in an environment with high electromagnetic interference (EMI). Then we suggest running the sensors in a metal sheath or conduit that is grounded to a suitable point outside the area of EMI. The sheath should extend entirely over the end of the thermistor. If shielded cable is used, then the shield should be grounded to the **Common** connection directly on your data logger.

Cable Lengths
The high resistivity of thermistors affords them a distinct measurement advantage over other methods when using long lengths of cable. For example, a thermistor probe that has a typical value of 10k ohms at 25°C will change its resistance about 4% per degree C. Even with 30m

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(100ft) leads (which may add an extra 10 ohm resistance) an error of less than 0.025°C will be introduced. The higher the resistance of the thermistor, the more negligible this error will become.

Keeping this in mind you will be able to run cables up to 30m (100ft) without appreciable accuracy degradation. If you intend on using longer cables, such factors as electrical noise and capacitance must be considered.

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1.16 APPENDIX D Sample Rates

Sample Rates

1.16.1 How a Data Logger Stores Readings

The sample rate of your data logger is the frequency with which it stores readings in its memory. A selected sample will apply for all channels on a SmartReader.

If you set your data logger's sample rate to eight seconds, it reads its input channels and stores the readings once every eight seconds. If you choose a sample rate longer than eight seconds, the logger still reads its input channels once every eight seconds, and stores an averaged reading at the end of the sample interval you have chosen.

For example, if you use a two-minute sample rate, the data logger takes fifteen separate readings over each two-minute interval. At the end of each two-minute interval, the logger calculates the average of the fifteen readings, and stores that average in its memory.

1.16.2 Sample Rate Tables

The following tables list the maximum time spans over which your SmartReader will record readings. The time spans depend on the number of channels enabled and the length of the sample rate. A SmartReader has a memory capacity of 32,767 readings.

In each table, the *Sample Rate* column lists the available sample rates. The *Days, Hours, Minutes* and *Seconds* columns list the time spans over which your logger will record readings at each sample rate.

For example, a SmartReader with two channels enabled, using a sample rate of ten minutes, will store readings for 113 days, 18 hours and 40 minutes. After that time, depending on how it was set up, the logger will either continue to take readings and replace the oldest readings with the new readings, or it will stop taking readings.

Table E-1: SmartReader Sample Rate - One Channel Enabled

Sample Rate	Days	Hours	Minutes	Seconds
8 sec.	3	0	49	4
16 sec.	6	1	38	8
32 sec.	12	3	16	16
56 sec.	21	5	43	28
2 min.	45	12	16	0
4 min. 56 sec.	112	6	15	28

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10 min.	227	13	20	0
20 min.	455	2	40	0
30 min.	682	16	0	0

Table E-2: SmartReader Sample Rate Table - Two Channels Enabled

Sample Rate	Days	Hours	Minutes	Seconds
8 sec.	1	12	24	32
16 sec.	3	0	49	4
32 sec.	6	1	38	8
56 sec.	10	14	51	44
2 min.	22	18	8	0
4 min. 56 sec.	56	3	7	44
10 min.	113	18	40	0
20 min.	227	13	20	0
30 min.	341	8	0	0

Table E-3: SmartReader Sample Rate - Three Channels Enabled

Sample Rate	Days	Hours	Minutes	Seconds
8 sec.	1	0	16	16
16 sec.	2	0	32	32
32 sec.	4	1	5	4
56 sec.	7	1	53	52
2 min.	15	4	4	0
4 min. 56 sec.	37	10	1	52
10 min.	75	20	20	0
20 min.	151	16	40	0
30 min.	227	13	0	0

Table E-4: SmartReader Sample Rate - Four Channels Enabled

Sample Rate	Days	Hours	Minutes	Seconds
8 sec.	0	18	12	16
16 sec.	1	12	24	32
32 sec.	3	0	49	4
56 sec.	5	7	25	52

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2 min.	11	9	4	0
4 min. 56 sec.	28	1	33	52
10 min.	56	20	0	0
20 min.	113	18	40	0
30 min.	170	16	0	0

Table E-5: SmartReader Sample Rate - Five Channels Enabled

Sample Rate	Days	Hours	Minutes	Seconds
8 sec.	0	14	33	44
16 sec.	1	5	7	28
32 sec.	2	10	14	56
56 sec.	4	5	56	8
2 min.	9	2	26	0
4 min. 56 sec.	22	10	48	8
10 min.	45	12	10	0
20 min.	91	0	20	0
30 min.	136	12	30	0

Table E-6: SmartReader Sample Rate - Six Channels Enabled

Sample Rate	Days	Hours	Minutes	Seconds
8 sec.	0	12	8	8
16 sec.	1	0	16	16
32 sec.	2	0	32	32
56 sec.	3	12	56	56
2 min.	7	14	2	0
4 min. 56 sec.	18	17	0	56
10 min.	37	22	10	0
20 min.	75	20	20	0
30 min.	113	18	30	0

Table E-7: SmartReader Sample Rate - Seven Channels Enabled

Sample Rate	Days	Hours	Minutes	Seconds
8 sec.	0	10	24	8
16 sec.	0	20	48	16

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32 sec.	1	17	36	32
56 sec.	3	0	48	56
2 min.	6	12	2	0
4 min. 56 sec.	16	0	52	56
10 min.	32	12	10	0
20 min.	65	0	20	0
30 min.	97	12	30	0

Table E-8: SmartReader Sample Rate - Eight Channels Enabled

Sample Rate	Days	Hours	Minutes	Seconds
8 sec.	0	9	6	8
16 sec.	0	18	12	16
32 sec.	1	12	24	32
56 sec.	2	15	42	56
2 min.	5	16	32	0
4 min. 56 sec.	14	0	46	56
10 min.	28	10	40	0
20 min.	56	21	20	0
30 min.	85	8	0	0

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